29 April 2004

Mr. Todd Borci
EPA - New England, Region 1
1 Congress Street, Suite 1100
Boston, MA 02114-2023

Mr. Len Pinaud
Massachusetts Dept. of Environmental Protection
20 Riverside Drive
Lakeville, Ma 02347

Subject: Impact Area Groundwater Study Program (IAGWSP)
USEPA Region I Administrative Orders SDWA 1-97-1019 & 1-20000-0014
Draft J-3 Range Groundwater Rapid Response Action (RRA) Plan

Dear Mr. Borci and Mr. Pinaud:

ECC is pleased to provide the Draft J-3 Groundwater Rapid Response Action (RRA) Plan, on behalf of the Army/National Guard Bureau's Impact Area Groundwater Study Program (IAGWSP) and the U.S. Army Corps of Engineers. We would appreciate comments by 1 June 2004.

Please contact Ben Gregson or Dave Hill at the IAGWSP or the undersigned if you have any questions regarding this matter.

Sincerely,

Eric Banks
Sr. Program Manager

cc:
Ben Gregson/Dave Hill/P. Richardson - IAGWSP
D. Margolis/Gina Kaso - USACE
M. Cassidy/D. Moyer - EPA
M. Panni - MADEP
T. Frendak/T. McCoun – AEC
R. Nida – NGB
H. Colby, AMEC
M. Goydas - Jacobs
P. Hunt - ECC

Impact Area Groundwater Study Program

DRAFT

J-3 Range Groundwater Rapid Response Action (RRA) Plan

Camp Edwards
Massachusetts Military Reservation
Cape Cod, Massachusetts

April 30, 2004

Prepared for:

U.S. Army Corps of Engineers
New England District
Concord, Massachusetts
for
U.S. Army / National Guard Bureau
Impact Area Groundwater Study Program
Camp Edwards, Massachusetts

Prepared by:

Environmental Chemical Corporation
Otis ANG Base, Massachusetts
Contract No. DACW33-02-D-0003, CTO 002

IMPACT AREA GROUNDWATER STUDY PROGRAM

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DISCLAIMER

This document has been prepared pursuant to government administrative orders (U.S. EPA Region 1 SDWA Docket No. I-97-1019 and 1-2000-0014) and is subject to approval by the U.S. Environmental Protection Agency. The opinions, findings, and conclusions expressed are those of the authors and not necessarily those of the Environmental Protection Agency.

NOTICE

The United States Department of Defense, Department of the Army, funded wholly or in part the preparation of this document and work described herein under Contract DACW33-02-D-0003. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

Draft

J-3 Range Groundwater Rapid Response Action (RRA) Plan

Camp Edwards
Massachusetts Military Reservation
Cape Cod, Massachusetts

April 30, 2004

CERTIFICATION:

I hereby certify that the enclosed J-3 Range Rapid Response Action (RRA) Plan, shown and marked in this submittal, is that proposed to be incorporated with Contract Number DACW33-02-D-0003, Contract Task Order 002. This Work Plan has been prepared in accordance with USACE Scope of Work and is hereby submitted for Government approval.

Reviewed by:

Paul C. Hunt for Siv Krishnan — 4/29/04

Contractor Quality System Manager — Date

Paul C. Hunt — 4/29/04

ECC Project Manager — Date

4/29/04

ECC Program Manager — Date

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ACRONYMS AND ABBREVIATIONS

2,4-DNT	2,4-dinitrotoluene
2A-DNT	2-amino-4,6-dinitrotoluene
3D	three-dimensional
4A-DNT	4-amino-2,6-dinitrotoluene
AFCEE	Air Force Center for Environmental Excellence
AMEC	AMEC Earth and Environmental, Inc.
ANG	U.S. Air National Guard
AO	Administrative Order
ASR	Archive Search Report
AVGAS	aviation gas
BBM	Buzzards Bay Moraine
BTEX	benzene, toluene, ethylbenzene, and xylenes
BV	bed volume
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act of 1980 (Superfund)
CFR	Code of Federal Regulations
CMR	Commonwealth of Massachusetts Regulation
COC	contaminant of concern
DoD	Department of Defense
DWEL	drinking water equivalent level
ECC	Environmental Chemical Corporation
EDB	ethylene dibromide
EPA	U.S. Environmental Protection Agency
ETR	extraction, treatment, and reinjection
FBR	fluidized bed reactor
FS	feasibility study
FS-12	Fuel Spill-12
GAC	granular activated carbon
gpm	gallons per minute
HDPE	high-density polyethylene
HMX	octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine

IAGWSP	Impact Area Groundwater Study Program
IART	Impact Area Review Team
Jacobs	Jacobs Engineering
JP-4	jet fuel-4
K	hydraulic conductivity
kg	kilograms
lb	pounds
LHA	Lifetime Health Advisory
LTGM	Long Term Groundwater Monitoring
MA	Massachusetts
MADEP	Massachusetts Department of Environmental Protection
MCL	maximum contaminant level
MCP	Massachusetts Contingency Plan
MDL	method detection limit
MGL	Massachusetts General Laws
MMCL	Massachusetts maximum contaminant level
mg/L	milligrams per liter
MMR	Massachusetts Military Reservation
MPP	Mashpee Pitted Plain
msl	mean sea level
MSP	Munitions Survey Project
MWDSC	Metropolitan Water District of Southern California
NGB	National Guard Bureau
O&M	operations and maintenance
OE	ordnance and explosives
PEP	pyrotechnic, explosives and propellant
PPE	personal protective equipment
PQL	practical quantitation limit
PRG	preliminary remediation goals
PRM	perchlorate-reducing microbes
psig	pounds per square inch—gauge
RCRA	Resource Conservation and Recovery Act
RDX	hexahydro-1,3,5-trinitro-1,3,5-triazine
RO	reverse osmosis

RRA	rapid response action
SDWA	Safe Drinking Water Act of 1974
SE	Southeast
SM	Sandwich Moraine
TCLP	Toxicity Characteristic Leaching Procedure
TERC	Total Environmental Restoration Contract
Textron	Textron Systems Corporation
TNT	trinitrotoluene
TOM	top of mound
TRET	Technical Review and Evaluation Team
UIC	underground injection control
USACE	U.S. Army Corps of Engineers
USGS	U.S. Geological Survey
UV	ultraviolet
UXO	unexploded ordnance
VOC	volatile organic compound
ZOC	zone of contribution
µg/L	micrograms per liter

EXECUTIVE SUMMARY

This *J-3 Range Groundwater Rapid Response Action (RRA) Plan* presents the assessment activities, modeling and conceptual design for use of components of the Fuel Spill-12 (FS-12) extraction, treatment and reinjection (ETR) system to capture and treat the J-3 plume. In addition, treatment technologies and design consideration recommendations are presented. This work has been conducted by the U.S. Army Corps of Engineers (USACE) under the Total Environmental Restoration Contract (TERC) DACW33-02-D-003, CT002 in support of the Impact Area Groundwater Study Program (IAGWSP), pursuant to U.S. Environmental Protection Agency (EPA) Administrative Orders (AOs) under the Safe Drinking Water Act (SDWA) and the Massachusetts Contingency Plan (MCP).

This RRA plan includes:

- summary of results of ongoing investigations and evaluations;
- preliminary design data needs (e.g., results of ongoing pilot/treatability studies, collection of groundwater elevation data in the J-3 plume area to address uncertainty in flow directions);
- initiation of wellfield design modeling (including determination of pumping rate requirements, flow rate distribution and screen length and assessment of impacts on the Fuel Spill-12 (FS-12) remedial system;
- identification of design criteria;
- regulatory considerations; and
- RRA schedule considerations.

The J-3 plume is located at the eastern border of the Massachusetts Military Reservation (MMR) Impact Area at Camp Edwards. This plume consists primarily of perchlorate and hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX), which is migrating in a southerly direction toward Snake Pond, located in the Town of Sandwich. The maximum concentrations of perchlorate and RDX detected in the plume to date are 311 micrograms per liter (µg/L) and 19 µg/L, respectively. No known private or public supply wells have been impacted by the J-3 Plume. Primary source areas for the plume in the J-3 Range are the former Melt/Pour building area and the Artillery Range/Demolition Area.

The FS-12 ETR system, which is located outside the eastern border of the MMR southeast of the J-3 plume, was designed to remediate the contaminants ethylene dibromide (EDB) and benzene, which originate near Greenway Road at the site of a pipeline release of aviation gas (AVGAS) and jet fuel-4 (JP-4). This system was brought on-line in 1997 and treats extracted groundwater using liquid-phase granular activated carbon (GAC). Treated water is returned to the aquifer through reinjection wells. The Air Force Center for Environmental Excellence (AFCEE) operates the FS-12 ETR system, which is owned by the Department of Defense (DoD).

A new Southeast (SE) Ranges flow and transport model and three-dimensional (3D) plume shells for RDX and perchlorate were developed. Transport simulations were conducted to evaluate the model-predicted trajectory of the J-3 RDX and perchlorate and to assess the potential for the FS-12 ETR system to capture the J-3 plume. Potential impacts to the FS-12 remedial system, specifically mass removal performance and long-term cleanup of the EDB plume, and potential impacts on ecological threshold compliance were also evaluated.

The J-3 capture scenario testing results indicate that existing wells 90EW0001, 90EW0002 and 90EW0003 (currently not operating) pumping at a cumulative rate of 100 gallons per minute (gpm) can capture the J-3 plume. Testing indicates that an additional extraction well (located either west of 90EW0001 or downgradient near the north side of Snake Pond) will not appreciably reduce aquifer restoration time frame. The difference in time for aquifer restoration with or without an additional sidegradient or downgradient well is less than one year. To assess how potential future remedial actions may impact the RRA treatment train design, transport simulations were also conducted to assess likely influent contaminant characteristics and flow rates if an additional in-plume extraction well (located upgradient of extraction well 90EW0001) is added to the wellfield. These results were used to conceptualize potential future flow rate expansion requirements and influent characteristics. These hypothetical in-plume wellfield scenarios are conceptual in nature. Due to the complex nature of the hydrogeologic setting in the area of Snake Pond and the equally complex juxtaposition of various plumes that are emerging as a result of the ongoing investigations, a detailed evaluation of comprehensive remedial strategies for this portion of the aquifer will not be possible until the ongoing groundwater investigations have been completed. Therefore, any detailed evaluation of in-plume groundwater extraction will be conducted following completion of the groundwater investigation report in conjunction with the required feasibility study.

The impact of the additional extraction and reinjection on the FS-12 system was modeled using the new SE Ranges model and the original FS-12 design model. Performance of the current FS-12 system and a modified system with wells 90EW0001, 90EW0002 and 90EW0003 operating at a combined flow rate of 100 gpm was compared in terms of EDB mass capture. The rate of EDB capture for the average condition was very similar (less than one year difference) to the anticipated performance of the FS-12 system with J-3 Range extraction. Approximately 99.8 percent of the FS-12 EDB mass was captured—consistent with design predictions and goals. This indicates that J-3 Range extraction using the three inactive FS-12 extraction wells should not adversely impact predicted FS-12 wellfield performance in regard to mass removal and overall remedy time frame. Evaluation of FS-12 capture zones confirmed complete capture of the FS-12 plume under the scenarios considered.

In order to estimate the effects of remedial pumping stress on nearby surface water bodies, the three-dimensional (3D) flow model was used to evaluate the impact of increasing flow rates in the FS-12 wellfield on ecological thresholds. The ecological thresholds were developed by the Technical Review and Evaluation Team (TRET) in 1996 to prevent potential adverse impacts on surface water bodies as a result of remedial pumping. The results indicate that the ecological thresholds will not be exceeded.

The limitations and flexibilities of the FS-12 piping and plant infrastructure were evaluated to determine the potential to use components of the FS-12 system. Design drawings and operational records were reviewed, and insights gained as a result of previous assessments of FS-12 system performance were considered.

Based on evaluation of probable adverse impacts on FS-12 GAC performance and plant operations and maintenance requirements, review of potential cost implications of increased carbon utilization, and likely difficulties in evaluating contaminant removal effectiveness, it was determined that using the influent header and combining the influent streams is not the optimal approach. Commingling the influent would require treatment and monitoring of removal performance for all of the contaminants of concern (EDB, benzene, RDX, and perchlorate) for the total combined flow rate (approximately 780 gpm) as compared to more selective treatment and monitoring of RDX and perchlorate at a much lower flow rate, approximately 100 gpm. In addition, the treatment of the commingled influent would potentially become inefficient (or not viable) as flow rates in the FS-12 wellfield are reduced with time. The FS-12 GAC system requires a minimum influent flow rate to be operational and functional.

The current configuration and flow/treatment capacity of the FS-12 facility treatment system and effluent were analyzed to determine treatment train interface and capacity issues. It was determined that sufficient floor space exists within the FS-12 plant building and that shared use of selected components of the treatment plant and wellfield (e.g., effluent holding tank, effluent pump and header, and reinjection wells) would be cost effective as compared to building a stand-alone treatment plant to treat the J-3 plume.

Various reports and pilot studies were reviewed for the process of perchlorate reduction via destructive processes, including biological, chemical, and electrochemical. Reports and pilot testing analysis for physical removal processes, including carbon adsorption, ion exchange, membrane filtration, and electrodialysis, were reviewed for the given application. Similarly, a literature review and an assessment of available pilot and treatability studies and full-scale applications on the treatment of RDX-contaminated water using carbon adsorption, ion exchange, oxidation, and biodegradation processes were conducted.

After reviewing the available information, performing a relative capital cost comparison, and coordinating with AFCEE on the design concept, the optimum treatment option was determined to be a GAC treatment comprised of a tailored GAC system for perchlorate removal and a non-tailored GAC system for RDX removal and polishing. Ion exchange was also found to be an acceptable, but a somewhat more costly alternative than GAC. The existing FS-12 treatment plant building can house (with modification) either GAC or ion exchange components to address the J-3 plume. The FS-12 facility has sufficient available space to treat 150 to 250 gpm, depending on the technology installed. The results of the Pew Road pilot study (available September 2004) will be reviewed and considered in the final design for the J-3 Range treatment system. The J-3 Range treatment system will be located within the existing FS-12 facility, but separate from the FS-12 treatment process.

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1.0 INTRODUCTION

The Impact Area Groundwater Study Program (IAGWSP) with support from the USACE is conducting investigations to assess soil and groundwater contamination resulting from the historical land uses at the Camp Edwards Impact Area and training ranges. Characteristics of the J-3 Range plume are evaluated and the rapid response action (RRA proposed) to mitigate further migration of the plume are identified in this document. Activities necessary to complete the assessment and conceptual design of the proposed RRA system are also included as part of this RRA plan.

MMR is located on upper Cape Cod, about 60 miles south-southeast of Boston. Approximately 15,000 acres of this 22,000-acre facility, referred to as the range, maneuver and Impact Area, have been used for military and law enforcement training (Figure 1-1). For over 46 years, the Camp Edwards training ranges and Impact Area have been used for military and law enforcement training in the use of small arms, mortars, heavy artillery, and ordnance demolition. In some areas, the spent shells and byproducts of the used munitions have resulted in environmental degradation of the soil and groundwater.

The J-3 Range, which is the southernmost of the four former training ranges that comprise the Southeast (SE) Ranges near the eastern border of the MMR, was also used for many years for weapons testing and development by Textron Systems Corporation (Textron), a defense technology contractor. The J-3 plume consists primarily of perchlorate and hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX) and originates near a former demolition area located in the central portion of the J-3 Range. The plume migrates south toward Snake Pond, located in the Town of Sandwich (Figure 1-2 and Figure 1-3). The J-3 plume footprint is currently situated northwest of the Fuel Spill-12 (FS-12) plume and FS-12 extraction, treatment and reinjection (ETR) system (Figure 1-3). Ongoing groundwater investigations have generated sufficient plume characterization and water quality data to assess the viability of implementing a rapid response action to initiate the cleanup of the J-3 plume.

Results and recommendations of an evaluation to test the feasibility of utilizing various components of the existing FS-12 ETR remedial system to capture and treat the adjacent J-3 plume are presented.

1.2 PURPOSE

The purpose of this RRA plan is to present the results of the evaluation conducted to determine capture requirements and viable treatment components to remove J-3 plume contaminants and to present a proposed conceptual design to address further J-3 plume migration. The plan also presents an overview of the activities necessary to complete the design and engineering phases of the project and associated implementation schedule. The conceptual design of the wellfield and treatment train emphasizes use of the existing FS-12 remedial system infrastructure. The goal of using the FS-12 system infrastructure would be to expedite J-3 system installation and startup time frames and to reduce system costs. An assessment of the FS-12 system (or modified system, if appropriate) for plume capture using components of the FS-12 system will be developed. Testing of additional hypothetical extraction wells assessed alternative well locations, both west and south of extraction wells 90EW0001, 90EW0002 and 90EW0003, to evaluate possible wellfield improvements beyond that provided by the existing FS-12 extraction wells. In addition, testing of a hypothetical design (the addition of an upgradient in-plume well) assessed possibly higher future system flow rate requirements and any resulting variability in influent concentrations to evaluate options for RRA treatment train selection and appropriateness. However, these alternatives were not aimed at determining wellfield requirements for a comprehensive remedy for the J-3 plume. Due to the complex nature of the hydrogeologic setting in the area of Snake Pond and the equally complex juxtaposition of various plumes that are emerging as a result of the ongoing investigations, a detailed evaluation of comprehensive remedial strategies for this portion of the aquifer will not be possible until the ongoing groundwater investigations have been completed. Therefore, any detailed evaluation of in-plume groundwater extraction will be conducted following completion of the groundwater investigation report in conjunction with the required feasibility study.

1.3 ADMINISTRATIVE ORDER GUIDANCE

Soil and groundwater investigations have been performed by the IAGWSP since 1997, pursuant to Safe Drinking Water Act (SDWA) Administrative Orders (AO), including 1-97-1019 (AO1) and 1-2000-0014 (AO3). The U.S. Environmental Protection Agency (EPA) also issued SDWA Administrative Order 1-97-1030 (AO2) prohibiting all planned detonation of ordnance and explosives at or near the training ranges and Impact Area, except for unexploded ordnance (UXO) activities. Under EPA A03, the IAGWSP is required to consider RRAs to protect the sole source aquifer beneath Camp Edwards. Pursuant to EPA's Administrative Orders, the IAGWSP has undertaken such interim actions to address soil and groundwater contamination.

1.4 REPORT ORGANIZATION

This report is divided into nine main sections and two appendixes. Section 1.0 is this introduction, which provides the purpose of the RRA plan and an overview of the document. Section 2.0 includes site description, history and ongoing groundwater investigations. Section 3.0 includes a description of the groundwater characteristics and the conceptual site model for the J-3 and FS-12 plumes. Section 4.0 is a review of regulatory considerations. Section 5.0 describes the conceptual design for the J-3 Groundwater ETR system, gives an overview of the groundwater fate and transport simulation scenarios conducted for wellfield design and presents the preliminary basis of design. Section 5.0 also summarizes the treatment technology evaluations conducted, the alternative development, and the proposed treatment train process. Finally, Section 5.0 provides an overview of the FS-12 treatment plant. Section 6.0 discusses the additional data requirements for system design and presents a description of the on-going Pew Road study and its intended use in finalizing treatment train design. Section 7.0 presents the performance monitoring plan requirements to monitor the J-3 Groundwater ETR system immediately before and after start-up and throughout operations. Section 8.0 presents a discussion of key timeframes for schedule consideration. Section 9.0 lists the references cited in this document. Appendix A includes discussion of contaminant plume shell development for the J-3 plume RDX and perchlorate. Appendix B includes a description of the SE Range flow and transport model development and a summary of previous modeling and data analysis related to understanding the flow conditions near the SE Ranges. Appendix B also describes wellfield scenario development, scenarios testing using flow (particle tracking analyses) and solute transport modeling, and model sensitivity and uncertainty. In addition, Appendix B presents the modeling of the J-3 capture requirements and the assessment of potential impacts on the FS-12 ETR system and discusses the fate and transport of the J-3 plume constituents, perchlorate and RDX. Appendix B also presents the impacts of the combined FS-12 and J-3 plumes pumping stress on established ecological thresholds.

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2.0 BACKGROUND

Historical site operations, geological and hydrogeological setting and site investigations conducted at J-3 and FS-12 are summarized in this section.

2.1 SITE DESCRIPTION AND HISTORY

MMR is located in the western portion of Cape Cod and occupies approximately 22,000 acres (35 square miles) within the towns of Bourne, Sandwich, Mashpee, and Falmouth in Barnstable County, Massachusetts (Figure 1-1). Military use of portions of the MMR began as early as 1911. Most of the activity, however, has been conducted since 1935 and has included operations by the U.S. Army, U.S. Coast Guard, U.S. Air Force, Massachusetts Army National Guard, U.S. Air National Guard, and Veterans Administration. The level of activity at MMR has varied over its operational history. Some specific activities have resulted in a number of contaminants being released into the environment, including the groundwater.

The Southeast Ranges are former training and defense contractor test ranges. Most of the activity on the ranges occurred between the 1950s and the 1970s, although the J-3 Range continued to be used into the late 1980s/early 1990s (AMEC 2001b). Defense contractor activities included open burning and detonation of explosives, disposal of wastewater, and disposal of munitions in burial pits. Military activities conducted in the area of the J-3 Range primarily involved small arms, mortar and grenade training.

The IAGWSP is continuing to investigate the extent of soil and groundwater contamination within and emanating from the Southeast Ranges. To date, investigations have identified several plumes associated with this area. The plumes vary in composition but are generally a mixture of RDX; HMX (octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine) and perchlorate.

2.1.1 J-3

The J-3 Range (Figure 1-2) was originally developed between 1935 and 1941 along the west side of Greenway Road under the designation of the H Range. It is approximately 600 feet wide by 3,200 feet long, with the long axis oriented northwest-southeast. The H Range was used into the 1950s as a mortar range. In 1968, the area was developed as a test range, under the designation J-3 Range. AVCO, which was purchased in 1985 by Textron, used the J-3 Range beginning in 1970 to develop and test tactical weapon systems for the U.S. Army and U.S. Air Force. Beginning in 1979, the Melt/Pour building was used for the melting and pouring of explosives into test munitions. The majority of activity at the range included loading, assembly, and explosive testing of tactical ordnance items. Other known activities included warhead deployment techniques, such as parachute drop, launcher deployment, and on-board sensor evaluation. Reportedly, warheads up to 100 (pounds) lb were tested at the J-3 Range (AMEC 2001a). In addition, the following activities are reported to have occurred on the range: burning of excess propellant and other explosive debris; disposal of process wastewater generated from milling of explosives at the J-3 Range Melt/Pour building area; release of wastewater (which may have contained explosives, metals and other contaminants) to subsurface drywells and leaching structures; and disposal of various items including spent munitions.

2.1.2 FS-12

The FS-12 plume is situated immediately East to the J-3 plume (Figure 1-3). As a result of earlier discovery, the conceptual model of the FS-12 plume and source area has been developed and refined for many more years than the J-3 plume. The FS-12 plume is primarily defined by exceedances of the Massachusetts Maximum Contaminant Levels (MMCL) for ethylene dibromide (EDB) and the federal maximum contaminant level (MCL) for benzene. EDB and benzene, toluene, ethylbenzene, and xylenes (BTEX) groundwater contamination was a result of a fuel pipeline break and persists within the groundwater over 30 years after the original spill. The primary contaminants of concern (COCs) in the FS-12 plume are EDB and benzene, and these contaminants define the plume boundaries; however, toluene is the only other BTEX component above the MCL. The benzene footprint generally lies within the EDB footprint (Figure 1-3). The origin of the FS-12 plume was a leak of approximately 70,000 gallons from a section of fuel pipeline near Greenway Road on the MMR. Both aviation gas (AVGAS) and jet fuel-4 (JP-4) were carried through the pipeline. The leaking pipeline section was repaired in 1972. Contamination associated with FS-12 was first identified when the Sandwich Water District installed two exploratory wells in 1990. The ensuing groundwater report concluded that fuel leaking from the pipeline had contaminated soil and groundwater in the immediate vicinity of Greenway Road (U.S. Air National Guard [ANG] 1995).

2.1.3 Geology

The geology of western Cape Cod comprises glacial sediments deposited during the retreat of the Wisconsinan stage of glaciation. Three extensive sedimentary units dominate the regional geology: the Buzzards Bay Moraine (BBM), the Sandwich Moraine (SM), and the Mashpee Pitted Plain (MPP). The BBM and the SM lie along the western and northern edges of western Cape Cod, respectively. The BBM and SM are composed of ablation till, which is unsorted material ranging from clay to boulder size that was deposited at the leading edge of two lobes of the Laurentide ice sheet during a readvance of the ice front during deglaciation. These moraines form hummocky ridges. The MPP, which consists of fine to coarse-grained sands forming a broad outwash plain, lies south and east of the two moraines. Underlying the MPP are fine-grained, glaciolacustrine sediments and basal till at the base of the unconsolidated sediments. In some areas these units are not evident and the sand of the MPP overlies bedrock.

The J-3 Plume is migrating through very transmissive unconfined sandy glacial outwash deposit. The sandy nature of the surface soils, promote rapid infiltration with little run-off. There are silty deposits in the lower section of the geology at J-3 where hydraulic conductivities are lower and groundwater velocities are reduced and some plume contaminants are restrained. In the vicinity of J-3, it appears the silt units are interbedded with sands; however, the silts do not directly overlie bedrock. South of the J-3 area, the silty lacustrine deposits overlie the granodiorite bedrock.

2.1.4 Hydrogeology

A single groundwater flow system underlies western Cape Cod, including MMR. The aquifer system is unconfined (i.e., it is in equilibrium with atmospheric pressure and is recharged by infiltration from precipitation). The high point of the water table occurs as a groundwater mound beneath the southeastern portion of Camp Edwards, immediately north of the J-3 Plume source area. Groundwater flow generally radiates outward from this mound. The ocean bounds the aquifer on three sides, with groundwater discharging into Nantucket

Sound on the south, Buzzards Bay on the west, and Cape Cod Bay on the north. The Bass River in Yarmouth forms the eastern lateral aquifer boundary.

Based on water table measurements and contaminant data, a distinct vertical gradient is distinguishable at wells immediately downgradient of the demolition area in the J-3 Range. This indicates notable downward flow near the top of the groundwater mound. Farther downgradient toward the midpoint of the plume, the vertical gradient flattens out, and where the plume approaches Snake Pond there is a clear upward gradient. Based on all available hydraulic and chemical data, the vertical gradients near the toe of the plume (adjacent and probably intersecting with the northern portion of Snake Pond) become more complex. Additional details of aquifer properties are provided in Appendix B.

2.2 SUMMARY OF INVESTIGATIONS

Based on investigations summarized in the following subsections, the principal environmental concerns identified to date at J-3 include the following:

- soils contaminated by explosives and propellants at a former Artillery Range and Demolition Area;
- soils contaminated by explosives in the vicinity of the Melt/Pour building area; and
- a contaminant plume (comprising two coalescent groundwater plumes) which has been identified in the vicinity and downgradient of the J-3 Range, apparently originating at or near the Demolition Area, Artillery Range, and the Melt/Pour building area in the center of the range. This plume has been mapped from its apparent source south to Snake Pond, which is located approximately 3,500 feet downgradient of the J-3 Range (Figure 1-3). Analytical results indicate that the plume is composed principally of two explosives, RDX and HMX, and the propellant perchlorate, and has been shown to extend as far south as the northern shore of Snake Pond. The plume's easternmost component, apparently originating near the Melt/Pour building area, is composed principally of HMX and RDX, and extends beneath Snake Pond. The plume's western component comprises primarily perchlorate and RDX, and originates from the Demolition Area. Additional information regarding groundwater contamination is presented in the Draft J-3 Range Supplemental Groundwater Workplan (AMEC 2003c).

2.2.1 Ordnance and Contaminant Investigations

Intensive investigative activities at the J-3 Range commenced in August 2000, and have been conducted in accordance with the following workplans and supplemental investigations.

- *Final J-1, J-3 and L Ranges Workplan* (Ogden 2000), August 2000;
- *Final J-1, J-3 and L Ranges Additional Delineation Workplan No. 1* (AMEC 2001c), September 2001; and
- *Final J-1, J-2 and L Ranges Additional Delineation Workplan No. 2* (AMEC 2002b), April 2002.

The following supplemental investigations were deemed necessary upon identification of explosives in both J-3 Range soils and in groundwater underlying or downgradient of the J-3 Range.

- *Final J-1, J-3 and L Ranges Interim Results Report*, TM 01-9. This report includes analytical data collected from the beginning of J-3 Range investigation in August 2000 through 2 March 2001 (AMEC 2001a), 29 March 2001;
- *Draft J-1, J-3 and L Ranges Interim Results Report No. 2*, TM 01-16. This report includes analytical data collected from the beginning of J-3 Range investigation in August 2000 through 27 July 2001 (AMEC 2001b), September 2001; and
- *Draft J-1, J-3 and L Ranges Additional Delineation Report No. 1*. This report presents analytical results from the beginning of J-3 Range investigation in August 2000 through 14 April 2002 (AMEC 2002a), 23 May 2002.

The investigative activities at the SE Ranges are components of a larger investigations program being conducted by the Army as part of the IAGWSP at Camp Edwards. Two other components of the program, the Munitions Survey Project (MSP) and the Archive Search Report (ASR) Project are investigations under which the IAGWSP pursued the discovery and/or exploration of previously unidentified potential source areas within the MMR boundary, including the J-3 Range. For the ground-based investigation, over 800 magnetic anomalies were reported in the J-3 Range. Certain individual and grouped anomalies were selected for investigation by inspection and excavation. These investigation results have identified a wide variety of non-ordnance and explosives (OE) materials as well as ordnance-related munitions, grenades, barrage rockets, fuses and other components. The

MSP has identified areas where geophysical surveys identified anomalous magnetic and electromagnetic fields. At other sites, buried munitions, other metallic material, and debris as well as other items of lesser investigative interest such as ferromagnetic rocks and man-made surface features (fences) have been shown to produce similar anomalous geophysical signals of the type observed at the J-3 Range. The areas exhibiting significant geophysical attributes have been located, described, and in some cases excavated and sampled in accordance with the EPA-approved MSP workplan, to characterize location and spatial distribution of potential disposal sites, munitions, debris and related contamination.

Soil grid sampling conducted by AMEC Earth and Environmental, Inc. (AMEC) during October 2001 immediately outside the Melt/Pour building area indicated the presence of explosive residue. Explosive residue was also detected in grab samples collected from the suspected location of a one-time release of process wastewater approximately 100 feet southwest of the former Melt/Pour building. In June of 2003, MACTEC conducted additional soil sampling, in a manner consistent with the AMEC grid sampling approach, to delineate the horizontal and vertical extent of the explosives residue in the surface soil around the Melt/Pour building.

The *Draft J-3 Range Supplemental Soil Workplan* (AMEC 2003b) summarizes source area characterization that is ongoing at the time of publication of this RRA plan. The objective of this continuing work is to better characterize known J-3 Range source areas and identify (and delineate) additional potential source areas not previously identified. At this time, the major sources resulting in the known J-3 Plume appear to be the Demolition Area and the Melt/Pour building area (Figure 1-2). Recently, detections of explosives and perchlorate in soils at the Hillside and Barrage Rocket areas indicate additional J-3 source areas in the northwestern section of the J-3 Range. However, any downgradient groundwater contamination related to these detections has not been fully characterized, and is not considered as a part of this RRA.

2.2.2 Groundwater Study

The characterization of soils from various areas within the J-3 Range is motivated, in part, by the presence of groundwater contamination in the vicinity and downgradient of the J-3

Range. Two distinct components of the J-3 plume have been identified. Analytical results indicate that the westernmost component, which emanates from the J-3 Range Demolition Area, is composed principally of RDX and perchlorate. The easternmost component of the plume emanates from the vicinity of the Melt/Pour building area, and is composed principally of HMX and RDX. For the sake of brevity in this report, these two plume sections are collectively referred to as the J-3 plume.

The latest documented characterization of the J-3 Plume is provided in the *J-3 Range Supplemental Groundwater Workplan* (AMEC 2003c). The workplan presents a comprehensive interpretation of existing groundwater and soil analytical results and the most recent hydrogeologic modeling conducted for the Southeast Ranges as of early 2003. The goal of the workplan (currently being finalized) is to identify data gaps and proposed investigative activities to fill those gaps. Activities include the installation and sampling of supplemental groundwater monitoring wells and additional modeling activities to support optimal well placement. Following submission of the draft workplan, significant improvements to hydraulic and chemical characterization of the J-3 Plume have been made. Much of these new data have been used to update the conceptual model of the plume (Section 3.2; Appendix A) and the Southeast Ranges model (Appendix B). At the time of writing the draft supplemental workplan, 40 wells had been installed at or downgradient of the J-3 Range under previous J-3 Range investigation workplans. Fifteen additional wells (J3P-32 through J3P-46) were recommended as part of the supplemental workplan, and several of these wells have now been installed and used for better plume delineation.

The IAGWSP has completed several modeling tasks pertinent to the J-3 Range Study Area. Previous modeling efforts have been used to aid in developing the plume conceptual model and more recently to simulate fate and transport. A regional groundwater flow model has been developed for analysis of the impacts of remedial system stress on plume migration and water supply evaluation. In addition, the regional model has been used to assess the migration of the top of the water table mound and its influence on flow directions and contaminant migration. This model also provided the boundary conditions for the higher resolution subregional model focused on assessing the Southeast Ranges plumes. Earlier models, as well as the latest model development, are summarized in Appendix B.

2.2.3 FS-12 Response Actions

A source removal effort in the vicinity of the pipeline break was initiated in October 1995. Approximately 75 gallons of free product was removed by early 1996, and it was estimated that 11 percent of the residual hydrocarbons was removed (approximately 44,579 lb). This was achieved through soil vapor extraction, air sparging and catalytic oxidation, and was completed in February 1998 (Air Force Center for Environmental Excellence [AFCEE] 2000).

The FS-12 ETR system was constructed in 1997 for containment and remediation of the FS-12 plume and was operational on 18 September 1997. The purpose of the FS-12 ETR system was to contain the FS-12 plume, preventing further migration of EDB and benzene. The FS-12 ETR system design specifications can be found in the *Draft Design Report for FS-12* (AFCEE 1996) and the *Final Technical Memorandum, Groundwater Modeling at FS-12* (AFCEE 1998a).

The FS-12 ETR system was designed to maintain hydraulic control, defined as 100 percent capture of the groundwater flow within the area where EDB exceeds the MMCL (0.02 micrograms per liter [µg/L]). The ETR system was designed to use closely–spaced extraction wells and reinjection wells having pumping rates well below the aquifer capacity so that any hydraulic impact on the aquifer, Snake Pond, and the nearby J. Braden Thompson plume would be minimal.

The FS-12 ETR was designed to extract 772 gallons per minute (gpm) from the aquifer using 25 extraction wells (Figure 1-3). Extraction wells 90EW0001, 90EW0002 and 90EW0003 were installed but not used in the final system design. These wells were not plumbed to the influent system. Eleven of the extraction wells are evenly spaced across the width of the plume near its downgradient extent and are referred as the southern toe extraction fence. Fourteen wells are located in or near the center of the plume where contaminant concentrations are highest and comprise the axial extraction fence. The groundwater is extracted and transferred through double-walled high-density polyethylene (HDPE) pipe to the FS-12 treatment plant where plume contaminants are removed by filtration through granular activated carbon (GAC). After treatment, the water is returned to the ground through 23 reinjection wells situated between the extraction wells and Snake

Pond and near the plume's downgradient extent. The FS-12 ETR system employs liquid-phase GAC to remove organic contaminants. The FS-12 ETR also uses greensand filtration for the removal of iron and manganese from the process train.

After system start-up, the extraction rate was increased to 782 gpm as a result of an evaluation of system performance and re-calibration of the groundwater model, as summarized in the *Second Quarter 1998 Fuel Spill 12 (FS-12) Performance Monitoring Evaluation (PME) Data Report* (AFCEE 1998b).

Detections of EDB above the MMCL in microwells under Snake Pond indicated that there was contamination of groundwater below Snake Pond and west of the reinjection fence beneath Snake Pond's northeastern shoreline. Wellfield modifications were made in an attempt to capture this contamination. On 2 June 2000, extraction wells 90EW0006 and 90EW0010 (Figure 1-3) were turned off to provide additional pumping capacity to the southern axial extraction wells and to help retard the movement of the contamination beneath the pond. On 25 July 2000, reinjection wells 90RIW0005 through 90RIW0009 were taken off-line to help pull the contamination near and west of these reinjection wells toward the axial fence. On 14 November 2000, reinjection well 90RIW0010 was taken off-line to also enhance extraction stress (by reducing reinjection mounding) and aid in pulling the contamination toward the extraction axial and toe fences. To address long-term capture of contamination beneath the pond, a design improvement was developed wherein reinjection well 90RIW0010 was converted to an extraction well (90EW0031). This extraction well came on-line on 1 June 2001 operating at 95 gpm, and was later increased to 125 gpm. Two additional reinjection wells, 90RIW0013 and 90RIW0014, located on the east side of Snake Pond were turned off as part of the new pumping scenario. This modification ensured capture of the area of groundwater contamination below Snake Pond and used 24 extraction wells and 15 reinjection wells operating at total flow rate of 800 gpm.

As influent and plant operating characteristics became better understood it was determined that chemical addition in the greensand filters for iron and manganese removal was no longer required. The greensand filters are still bedded with greensand material and are acting as a sand filter for solids.

The current (late 2003) operating condition uses a total of 19 extraction wells pumping at a total flow rate of 688 gpm. The extraction well network includes seven extraction wells spaced evenly across the width of the plume near the downgradient extent of the plume (southern toe extraction fence) and 11 extraction wells in a longitudinal array where the contaminant concentrations are highest (axial fence). One extraction well (90EW0031) is used to remediate a small plumelet located between the main plume and the eastern shore of Snake Pond. Treated groundwater is returned to the aquifer through a series of 17 reinjection wells situated on the flanks of, and downgradient of the southern toe extraction fence. The performance of the system is presented in the *Final FS-12 2002 Annual System Performance and Ecological Impact Monitoring Report* (AFCEE 2003).

2.3 ONGOING AND PLANNED INVESTIGATIONS AND STUDIES

The following subsections summarize ongoing and planned investigations and studies relevant to the J-3 Plume.

2.3.1 Long-Term Groundwater Monitoring

The objective of the Long Term Groundwater Monitoring (LTGM) Plan is to provide the necessary data to evaluate concentration trends over time and to monitor contaminant migration. LTGM will be continued at J-3 in accordance with the revised Appendix B for the LTGM Plan (AMEC 2002c). Each newly installed well is sampled for three rounds prior to being considered for inclusion in the LTGM Plan.

2.3.2 Plume Delineation

Various areas within the J-3 Range boundaries have been investigated as potential sources of the observed groundwater contamination. Based on the presence of pyrotechnic, explosives and propellant (PEP) compounds in soils, the Melt/Pour building area, the Artillery Range area, and the Demolition Area (including the Detonation Pit) are the most likely potential source areas. Three other areas near the J-3 Range are also under investigation as potential source areas because of either the visual observation of ordnance and munitions related materials at the surface or a known history of missile testing that included quantities of explosives. Recently, soil contamination has been detected in these areas. These three areas are the Minuteman 1 Test Area (known use of explosives during tests), the Hillside Study Area (observed OE in presumed impact area) and the Barrage Rocket Study Area (observed OE in presumed impact area). These areas are undergoing investigation to determine the nature and extent of soil contamination and their existing or potential contribution to groundwater contamination.

Plume delineation will be revised as new wells and sample data from existing wells become available. Verification of plume conceptual model updates will be based on discussions with the EPA and the Massachusetts Department of Environmental Protection (MADEP). Additional plume delineation is planned prior to completion of a draft J-3 Range Groundwater Report.

As discussed in the *J-3 Range Supplemental Groundwater Workplan* (AMEC 2003c), several wells are planned to fill in data gaps in the J-3 Plume. Many of these wells are yet to be installed. Future well installations will focus on better characterizing the following plume areas:

- the mid-plume western boundary;
- the area where the J-3 Plume intersects/underflows the northern section of Snake Pond;
- in-plume, to better characterize plume mass;
- south of Snake Pond, to identify possible plume underflow; and
- downgradient of the Hillside and Barrage Rocket areas.

The conceptual model of the plume will be updated as the upcoming drilling and sampling data are collected, and new plume shells (Appendix A) are developed. This updated information will then be used to confirm or revise the remedy outlined in this plan prior to implementation, and will be used during the groundwater report/feasibility study to assess plume fate and transport and to support final plume response decision-making.

2.3.3 Groundwater Modeling

A regional groundwater model encompassing all of MMR has been developed and continually updated as new data are collected. A subregional groundwater flow model targeting the Southeast Ranges area was cut from the larger regional model so that flow and solute transport of the J-Ranges could be simulated. For this RRA, modeling using this new subregional model was conducted to determine whether the J-3 Plume could be addressed using existing FS-12 wells and to test the appropriateness of other hypothetical extraction scenarios. The details of this modeling are provided in Appendix B.

Refinement of the regional and subregional models, as well as the conceptual model of the J-3 groundwater plume, is ongoing. Available hydraulic (water elevation) data will be used in the future to improve the Southeast Ranges model and to better predict plume fate and transport. Future modeling activities for J-3 will include preparation of a recalibrated regional and subregional model. The revisions will include additional data from new boreholes (e.g., bedrock elevations, local hydrostratigraphic variability); updated active pumping information; and new water table data. The updated model will be used to confirm the RRA design, support fate and transport evaluations presented in the groundwater report, help evaluate remedial alternatives in the feasibility study and support final system design.

3.0 GROUNDWATER CHARACTERIZATION

COCs have not been formally identified in the J-3 Plume. However, a Risk Screening Evaluation has been conducted to help identify the contaminants to be addressed as part of this RRA.

3.1 CONTAMINANT IDENTIFICATION

Based on available data, the following explosive and propellant compounds have been identified in the J-3 Plume.

- 1,3,5-trinitrobenzene;
- 2,4,6-trinitrotoluene;
- 2-amino-4,6-dinitrotoluene;
- 4-amino-2,6-dinitrotoluene;
- hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX);
- octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine (HMX); and
- picric acid.

Perchlorate has been identified as a constituent of the J-3 Plume. Perchlorate originates as a contaminant in the environment from the solid salts of ammonium, potassium, or sodium perchlorate. It is found in munitions, primarily as a component of explosive initiating devices (fuses) or spotting charges, but also occurs as a constituent of the explosive filler in a limited number of munitions. Ammonium and potassium perchlorate are manufactured for use as the oxidizer component and primary ingredient in solid propellant for rockets, missiles, and fireworks, in addition to being used in some delay compositions, flares, signaling devices, other pyrotechnics, smokes, and tracers.

The presence of the explosive and propellant compounds in groundwater is consistent with the following observations:

- Perchlorate is a component of inert munitions, fireworks, rocket propellants and pyrotechnics that were likely disposed of at the Demolition Area.
- RDX was probably the most heavily used explosive at the Demolition Area and Melt/Pour building area.
- HMX was a primary explosive.
- Perchlorate, RDX, and HMX were detected in soil at the J-3 Range.

A risk screening was completed to determine whether detected concentrations of HMX, perchlorate and RDX are at levels that exceed risk-based concentrations. The risk screening was completed to identify the presence of risk at the site and to further support the need for completion of the RRA.

For the purposes of the screening, preliminary remediation goals (PRGs) that are risk-based values for screening concentrations of contaminants in environmental media were used. The PRGs are established and published by EPA Region 9. The PRGs for RDX, perchlorate and HMX are presented in Table 3-1. Only HMX, perchlorate, and RDX were evaluated as part of the risk screening. Other regulatory criteria for HMX, perchlorate and RDX are discussed in Section 4.3.

Other chemicals may be present in groundwater at levels of concern. However, the RRA is being implemented to address only RDX, perchlorate, and HMX. A full characterization of groundwater and a determination of associated risk will be completed during the groundwater report.

The PRGs were used to screen all HMX, perchlorate and RDX analytical results from wells in the J-3 Plume (Attachment 3-1). Table 3-1 summarizes the screening results. As indicated in Table 3-1, the PRG for HMX was not exceeded by any of the detected concentrations in groundwater associated with the J-3 plume. However, the PRG for RDX and perchlorate was exceeded 145 and 62 times, respectively. Hence, based on comparison to the PRGs, both RDX and perchlorate are at concentrations in groundwater that may cause adverse effects to humans if consumed as drinking water over a lifetime. This will be further evaluated in the Groundwater Report.

The weight of evidence from this analysis suggests that there is a tangible risk reduction achieved by a plume capture system upgradient of Snake Pond.

For the purposes of this RRA, perchlorate and RDX were used as the primary constituents for modeling, treatability assessment and system evaluation.

3.2 CONCEPTUAL SITE MODEL

The following sections present the conceptual site model for the J-3 and FS-12 plumes. Relatively recent modeling and investigative efforts have been used to aid in developing the site conceptual model for the J-3 area. As noted, extensive prior investigations in the FS-12 area have been used to refine the site conceptual model.

3.2.1 J-3

RDX, HMX and perchlorate reside on the soil surface as particulates and residuals deposited as a result of historical activities. The contaminants may be concentrated (e.g., the Demolition Pit) or more diffuse, in the form of particulates. Water from rain or snowmelt passing through the soil dissolves these soluble contaminants and they become mobile and leach through the vadose zone to the water table, which is approximately 41 feet below the ground surface in the J-3 source area. Currently at J-3, contaminants are present in both soil and groundwater, indicating that source contamination has not been completely dissolved and may represent a residual source. The existence of a continuing source is substantiated by the presence of groundwater contamination near the water table beneath the J-3 Range.

The J-3 and adjacent FS-12 plumes migrate through an unconfined aquifer that is composed of sandy glacial outwash, which is very transmissive. Recharge occurs through precipitation and water loss is primarily due to evapotranspiration. The sandy nature of the surface soils promotes maximum infiltration with little run-off to surface water bodies. There are silty deposits in the mid and lower sections of the aquifer near J-3 and FS-12 where hydraulic conductivities (K) are lower (relative to the more permeable sands) so groundwater moves much slower in these deposits. Several of these silty glaciolacustrine deposits have been identified in the location of the mapped bottom of the J-3 and FS-12 plumes (see

Appendix B). The base of the unconsolidated aquifer is bound by granodiorite bedrock. In some places, a poorly sorted glacial till can be found overlying bedrock.

The current downgradient extent of perchlorate contamination is approximately 3,700 feet from the source area, whereas monitoring data indicate that RDX extends approximately 4,500 feet downgradient (Figure 1-3). It is also apparent that groundwater contamination extends farther beneath the pond, so the actual plume length is not accurately known. Based on perchlorate and RDX concentrations in available groundwater data, the plume has a maximum east-west width of approximately 1,200 feet and a maximum thickness of approximately 90 feet.

Although the J-3 Plume contains HMX, the plume extent is largely defined by the distribution of RDX and perchlorate contamination. Also, groundwater concentrations of HMX in the J-3 Plume are much lower than the health advisory level (400 µg/L). Hence, the J-3 Plume conceptual model focuses on the nature and extent of RDX and perchlorate contamination. The maximum concentrations of RDX, HMX and perchlorate in the plume are 20 µg/L, 88 µg/L and 311 µg/L, respectively.

The general mapped distribution of contaminants from the source area to Snake Pond aligns with the general groundwater flow direction (roughly north-south), displaying a subtle curvature toward the west near the center of the plume and a more easterly curvature as the plume approaches Snake Pond. Fate and transport modeling suggests that a 35 to 40-year travel time is necessary to develop the plume from the inferred source area to its current mapped distribution near the north side of Snake Pond. This prediction is consistent with a calculated average linear groundwater velocity of 0.31 feet per day across the length of the J-3 Plume. Because of the low retardation factors for perchlorate (Rf = 1.0) and RDX (Rf = 1.05), these contaminants travel at or near the velocity of groundwater. Recharge accretion has produced a downward slope of contamination downgradient from the source area. Approximately 1,700 feet downgradient, the plume levels off to a more horizontal trajectory for several hundred feet. Appendix A provides more details of the plume's vertical distribution and internal concentration gradients, and a series of plume cross-sections are provided in the *Draft J-3 Range Supplemental Groundwater Workplan* (AMEC 2003c).

The pattern of contamination near Snake Pond is generally consistent with a converging flow field as groundwater discharges to the pond. Monitoring data for RDX and perchlorate, groundwater head data, and groundwater modeling results indicate an upward flow trajectory beneath the northern bay and northern portion of the main basin of Snake Pond. Screening data from a borehole (MW-171) on Snake Island (the isthmus), recent push-boring samples from the U.S. Geological Survey (USGS) (November 2003), sporadic detects of perchlorate in pond drivepoints (a total of two detects out of 17 drivepoint samples; USGS 2003) and modeling of pond aquifer characteristics, indicate that at least a portion of the plume may be discharging to the pond just south of the island. The aquifer properties and contaminant distribution beneath the pond have been inferred because there are no data from beneath the pond (i.e., near or south of the pond's hinge line). To date, no RDX or perchlorate has been detected in groundwater or surface water downgradient of the pond. The current and future proportion of the plume passing beneath the pond is not well known, and is currently modeled based on reasonable assumptions. Because of the lack of data beneath the pond, it is difficult to predict the future configuration of the plume if there is no remedial action taken. The contaminant distribution (geometry of the plume) will likely remain similar to current conditions near and beneath the northern neck of Snake Pond, although concentration magnitudes may vary.

3.2.2 FS-12 Plume

The FS-12 plume originates at the source area on Greenway Road. The water table at the source area is approximately 70 feet below ground surface. The extent of the FS-12 plume is largely determined by the distribution of EDB. EDB contamination in FS-12 groundwater exceeds contamination by other FS-12 contaminants in terms of volume and in terms of the number of MMCL/MCL exceedances. The FS-12 plume is fragmented into three zones: (1) the source area (a relatively small area containing EDB and BTEX in the northern section along Greenway Road); (2) the plume core (the largest zone with the most mass, the axial extraction fence at its core, and bordered to the south by the southern toe extraction fence); and (3) the plumelet (a small zone of low EDB mass bordering the northeast side of Snake Pond). The plumelet is approximately 250 feet long and 100 feet wide with an approximate thickness of up to 60 feet. The lower boundary overlies lower conductivity silty sands. The upper boundary of the plumelet is approximately 80 feet below the water table and therefore, well below the bottom of Snake Pond (maximum depth = 33 feet). The plume core is oriented in a southwest direction, and travels nearly parallel to the northeastern shoreline of Snake Pond.

The contaminant distribution within the FS-12 plume resulted from a combination of the differential solubilities of the contaminants at the source area, the retardation of those contaminants by the organic matter present in the soil and sediment, and by significant aerobic biodegradation of the fuel. EDB forms a distinctive plume front and travels ahead of the remaining BTEX compounds. This is due to higher solubility and lesser susceptibility to biodegradation of EDB in comparison to BTEX.

In its most current depiction, the FS-12 plume extends from the source area approximately 4,000 feet to the southern toe fence, although fragmented into separate zones, is approximately 900 feet wide at its widest point, and 40 to 60 feet thick (AFCEE 2003). The FS-12 plume core is detached from the source area. The highest measured recent concentration of EDB in the plume is 21 µg/L in monitoring well 90MW0106. In contrast, at system startup the plume was 5,000 feet long, 2,300 feet wide and 150 feet thick with EDB concentrations exceeding 500 µg/L. The FS-12 ETR system is successfully collapsing the plume as pumping stress has pulled the boundaries of the plume toward the extraction fence. Additionally, the FS-12 ETR system is effectively reducing contaminant mass, restoring contaminated portions of the aquifer and providing total capture of the FS-12 plume.

4.0 REGULATORY CONSIDERATIONS

Several federal and state laws and regulations and other regulatory considerations are applicable to this proposed RRA pursuant to AO3. This section discusses these requirements including the MCP, feasibility studies, and groundwater treatment and recharge requirements.

4.1 MASSACHUSETTS CONTINGENCY PLAN CONSIDERATIONS

This RRA Plan is being developed pursuant to AO1 and AO3. AO3 requires the NGB and the Massachusetts National Guard to implement rapid response actions and remedial actions to address contamination that presents a potential threat to the Cape Cod sole-source aquifer. Pursuant to Section X of the AO3, all response actions conducted under the SDWA must meet or exceed the substantive cleanup standards of Massachusetts General Law (MGL) c. 21E and the MCP (310 CMR 40.0000 et seq.). AO3 (Section XXII.E) also requires the Respondents to coordinate the Army work under the SDWA AOs with the response actions being undertaken by the Air Force under CERCLA.

MADEP has a review process for determining the need for a response action based on the type of release, site conditions and receptors. Each of these items is discussed in the RRA Plan along with additional information to include response action objectives, specific plans for the action, schedules, approach for environmental monitoring, etc.

A description of the release and site conditions is discussed in Sections 2.1, and 3.0. Response actions undertaken to date at the site are addressed in Section 2.2. The reasons for implementing a response action and any associated requirements are addressed Section 1.0 and 3.1. The objective(s), specific plan(s), and the proposed implementation schedule considerations for the response action, including sketches of the proposed remedial installations are addressed in Sections 1.0, 5.0, 6.0, and 8.0. Discussions regarding whether remediation waste will be excavated, collected, stored, treated, or reused at the site are presented in Sections 4.3 and 5.0. The proposed environmental monitoring plan for implementation during and/or after the response action is addressed in Section 7.0.

4.2 FEASIBILITY STUDY ACTIVITIES

Following completion of the groundwater report, an FS will be prepared to evaluate potential comprehensive remedial alternatives to address the J-3 Plume in accordance with AO3. The comprehensive remedy will be selected based on a comparative analysis of the remedial alternatives presented in the FS.

4.3 GROUNDWATER TREATMENT/RECHARGE REQUIREMENTS

The purpose of this section is to evaluate pertinent local, state and federal laws, regulations, and guidance that impact the design and implementation of an RRA for the J-3 Demolition Area plume using components of the FS-12 remedial system. The action proposed consists of using certain components of the existing FS-12 ETR system currently operated by AFCEE under Comprehensive Environmental Response, Compensation and Liability Act of 1980 (CERCLA) to capture and treat perchlorate- and explosives-contaminated groundwater associated with the J-3 Range Plume.

A SDWA/CERCLA coordinated action for the J-3/FS-12 plumes will require compliance with certain federal, state and local requirements. The regulatory considerations for this action under AO3 are listed in Table 4-1 along with the governing authority/citation, synopsis and the specific action to be taken to address the consideration. A brief discussion of the principle provisions follows.

4.3.1 Drinking Water Standards

Appendix A, Section II.A.2 to AO3 notes that all rapid response actions must be designed to assure that all drinking water standards, including Lifetime Health Advisories (LHAs), Drinking Water Equivalent Levels (DWELs), and Safe Drinking Water Act (SDWA) maximum contaminant levels (MCLs), are met in groundwater underlying and downgradient of the areas of concern.

The EPA has promulgated SDWA MCLs (40 CFR 141-143) that are enforceable standards for public drinking water supplies. The standards protect drinking water quality by limiting the levels of specific contaminants that can adversely affect public health and are known or anticipated to occur in public water systems. EPA has granted Massachusetts primary enforcement authority for the SDWA primary drinking water regulations. Cleanup up goals established for both the FS-12 and J-3 actions considered federal MCLs, where available, under the federal SDWA and the Massachusetts MCLs (MMCLs) (310 CMR 22.00 et. seq.). The FS-12 COCs (EDB and benzene) have established MCLs/MMCLs. The J-3 plume contaminants (perchlorate and RDX), however, do not have established federal or state MCLs. Therefore, other criteria (LHAs and DWELs) were considered.

LHAs establish the concentration of a chemical in drinking water that is not expected to cause any adverse non-carcinogenic effect over a lifetime of exposure with a margin of safety. A DWEL represents the concentration of a substance in drinking water that is not expected to cause any adverse non-carcinogenic health effects in humans over a lifetime of exposure. The DWEL is calculated assuming that all exposure to the chemical comes from drinking water. LHAs and DWELs are not enforceable standards but are simply guidelines. For RDX, EPA recommends a LHA of 2 µg/L.

The EPA has also issued guidance regarding perchlorate cleanup levels. The federal EPA issued interim guidance in 1999 that recommended using provisional cleanup levels in the range of 4 to 18 µg/L for perchlorate in drinking water (EPA 1999). In January 2003, the EPA issued guidance that reaffirmed its 1999 interim guidance, with an added suggestion to carefully consider the lower end of the provisional range (EPA 2003). EPA considered this range to be protective based on ongoing analyses and taking into account the most sensitive receptors and noted that no additional adjustment for childhood exposure was needed (EPA 2003). EPA stated that this interim guidance would remain the applicable guidance until supplanted by new guidance based on a finalized environmental risk assessment (EPA 2003).

4.3.2 Additional Regulatory Considerations

The Federal Hazardous Waste Operations and Emergency Response regulations (29 CFR 1910.120) describe training, monitoring, planning, and other activities required to protect the health of workers performing hazardous waste operations. These regulations will be followed to protect the health of the workers during remediation activities that may involve hazardous waste. Federal Occupational Safety and Health Administration regulations for construction (29 CFR 1926, Subpart P) are also available and define safety requirements for construction and excavation activities. Work crews will fulfill these requirements, as applicable.

Sections 310 CMR 40.0300 – 40.0336 of the State's MCP, establish requirements for notifying state and local authorities of releases or threats of releases of oil and hazardous material. Notification of current releases has already been done. Notification of any new releases or spills will be submitted to the appropriate authorities in compliance with these requirements.

5.0 CONCEPTUAL DESIGN OF THE ETR SYSTEM

This section presents the methodology used to develop the conceptual design for the J-3 plume ETR System based on the site conceptual model, groundwater modeling, relevant regulations, treatment technology evaluations, bench-scale studies, and other engineering considerations. Extraction, treatment, and recharge was selected as the remediation approach because it is compatible with likely future comprehensive response actions and input from the EPA, MADEP, IAGWSP, USACE, and AFCEE. In addition to achieving remedial action goals and regulatory requirements, a primary objective is to integrate the J-3 Range ETR system within the existing infrastructure and system capabilities of the FS-12 facility without adversely affecting FS-12 system operations.

5.1 EXTRACTION SYSTEM

The feasibility of using FS-12 wells 90EW0001, 90EW0002 and 90EW0003 to capture the J-3 plume was evaluated with groundwater transport modeling. The following sections present the hydraulic scenario simulations and proposed wellfield design.

5.1.1 Fate And Transport Modeling

Groundwater transport modeling was conducted with the 2003 Southeast Ranges Groundwater Model (SE Range model) to evaluate the model-predicted trajectory of the J-3 RDX and perchlorate and to assess the potential for FS-12 wells 90EW0001, 90EW0002 and 90EW0003 to capture the J-3 plume. Potential impacts to the FS-12 remedial system, specifically mass capture performance of the EDB plume, and potential impacts on ecological threshold compliance were also evaluated.

5.1.1.1 J-3 Range RDX Transport Scenarios

The SE Range model was used to conduct flow and transport simulations for this RRA (Appendix B). The 2001 AFCEE regional model (AFCEE 2002a) was used as the basis for the development of the SE Range model. A complete discussion of the development of the SE Range model is presented in Appendix B. During the period of time modeling was conducted for this RRA, the SE Range model was recalibrated based on recently collected data from the study area, including water elevations from a synoptic water level survey of monitoring wells in the vicinity of the TOM and SE Ranges in August 2003. The evaluations presented in this section refer to those conducted with the original SE Ranges model. Similar transport simulations were conducted with the recalibrated model, and results of these are presented in Appendix B.

Thirty-three transport simulations of J-3 plume perchlorate and RDX and FS-12 EDB transport were conducted with the SE Ranges model. These included two types of transport simulations, 1) of an RDX release in the J-3 source area intended to mimic the development of the plume and 2) of the current RDX and perchlorate plume. Simulations of active remediation of the J-3 Plume featured cumulative pumping rates for FS-12 wells 90EW0001 through 90EW0003 from 75 to 200 gpm. Many of these simulations assumed that the start of pumping would be delayed approximately one year (to 2004.5) to accommodate additional study, design, and field implementation.

Variations of the three well configuration were tested, including additional extraction wells located either along the north shore of Snake Pond and to the west of extraction well 90EW0001. These simulations were conducted to determine if additional extraction wells or variations in well placement would significantly improve capture of the RDX plume. To assess how potential future remedial actions may impact the RRA treatment train design, transport simulations were also conducted to assess likely influent contaminant characteristics and flow rates if additional in-plume wells (located upgradient of extraction well 90EW0001) are added to the wellfield. Discussion of scenario results is limited to the one-year delayed pumping run, with cumulative flow rates from FS-12 extraction wells 90EW0001, 90EW0002 and 90EW0003 of 100 gpm. A complete discussion of the source area, no-action and additional well scenarios is presented in Appendix B.

To assess transport behavior of the existing J-3 RDX plume, a plume shell was created and mapped into the model grid. The plume shell was based on a 3D interpolation of field data and represents current contaminant distribution (see Appendix A). The total aqueous phase mass in the plume shell was 3.2 kg with a maximum concentration of 19.0 µg/L. After mapping the concentrations in the transport model grid, 99.54 percent of the plume mass was incorporated into the model with a maximum concentration of 17.56 µg/L. The drop in concentration is a result of interpolation from the plume shell grid to the transport model grid by the plume-mapping program. It is noted the maximum historical and recent RDX concentrations are 19 µg/L and 15 µg/L, respectively. The total mass in the model, after accounting for adsorption, was 3.4 kg. Additional discussion of plume shell development is included in Appendix A. It is noted the simulations presented here do not include a continuing source term. This assumption will not affect simulation of capture requirements. However, if the source is not addressed, the predictions presented herein will likely underestimate remedial time frames.

5.1.1.2 Proposed Wellfield RDX Modeling Results

Based on the results of the groundwater transport modeling, it was determined that a combined flow rate of 100 gpm from extraction wells 90EW0001, 90EW0002 and 90EW0003 was required to capture the J-3 plume and that reinjecting the treated water through existing FS-12 reinjection wells would not adversely impact the performance of the FS-12 remedial system (Figure 5-1a, Figure 5-1b and Animation 5-1). Although simulations indicated a cumulative flow rate of 75 gpm from the three FS-12 extraction wells was adequate to prevent further downgradient migration of the RDX plume from the extraction well locations, 100-gpm is proposed based on the flow rate requirement to capture the perchlorate plume. The final requirement for flow rate, flow distribution and appropriate screen intervals will be determined during the final well field design.

In the 100 gpm scenario, flow rates were distributed with 90EW0001 pumping 50 percent of the total, and 90EW0002 and 90EW0003 each pumping 25 percent of the total. The modeled scenarios simulated that the extraction wells would be packered along the top 20 ft of their screen interval to focus the hydraulic stress at elevations coincident with the J-3 plume. The extraction well pumps are expected to be located at an elevation of approximately 10 ft msl, or approximately 70 to 90 feet below the ground surface, depending on ground surface elevation. The FS-12 remedial system was simulated at its average operational flow rates as measured between 1 April and 30 June 2003. Reinjection of the additional water extracted from wells 90EW0001, 90EW0002 and 90EW0003 was distributed equally among FS-12 wells 90RIW0013 through 90RIW0017 and 90RIW0028 through 90RIW0030.

A graph of model-predicted mass capture over time by the FS-12 remedial system indicates that with no additional extraction, the existing FS-12 extraction wells capture a small amount (0.21 kg) of the current RDX plume after 40 years (Figure 5-2). Most of this mass is captured by the axial extraction wells after 2025, when the FS-12 system will likely not be active. A total of 2.50 kg of RDX mass is captured by the FS-12 system with 90EW0001, 90EW0002 and 90EW0003 pumping at 100 gpm (Figure 5-2). According to the model, most of the RDX plume that is not captured by FS-12 extraction wells is trapped in silt units or discharges to Snake Pond (Figure 5-3). The graph indicates that approximately 0.5 kg escapes capture (most of this mass is currently situated downgradient of the extraction wells and the capture zone) and discharges to the pond.

Maximum model-predicted influent RDX concentrations for the 100-gpm scenario were 1.25, 0.58 and 0.13 µg/L in extraction wells 90EW0001, 90EW0002 and 90EW0003, respectively. The maximum blended concentration for the three wells is 0.69 µg/L. If the flow from these wells were incorporated (blended) into the influent of the current FS-12 treatment train (assuming the current flow rate of 688 gpm remains constant), the maximum predicted concentration is 0.09 µg/L.

5.1.1.3 <u>J-3 Range Perchlorate Transport Scenarios</u>

Perchlorate transport modeling included simulations of current conditions and, similar to RDX, a series of scenarios under average operating conditions for the MMR remedial systems and modified cases with FS-12 extraction wells 90EW0001, 90EW0002 and 90EW0003 and other hypothetical extraction wells actively pumping. A complete discussion of the development and results of these simulations is included in Appendix B. Discussion of scenario results in this section is limited to the one-year delayed pumping run, with cumulative flow rates from FS-12 extraction wells 90EW0001, 90EW0002 and 90EW0003 of 100 gpm. Similar to the transport simulations of RDX, the 100-gpm perchlorate simulation does not include a continuing source term. This assumption will not affect simulation of capture requirements. However, if the source (soils) is not addressed, the predictions presented herein will likely underestimate remedial time frames.

A perchlorate plume shell was also created (using 3D interpolation of field data) and mapped into the SE Ranges model for transport. The plume shell had a total mass of 19.4 kg with a maximum concentration of 310.6 µg/L. After mapping the concentrations in the transport model grid, 99.6 percent (19.3 kg) of the plume mass was incorporated into the model with a maximum concentration of 300.0 µg/L. It is noted that the observed maximum historical and recent concentrations are 311 µg/L and 310 µg/L, respectively. Additional discussion of plume shell development is included in Appendix A.

5.1.1.4 Proposed Wellfield Perchlorate Modeling Results

Perchlorate transport under the proposed 100-gpm scenario indicates that the three existing extraction wells effectively capture most of the upgradient perchlorate mass (Figure 5-4a, Figure 5-4b and Animation 5-2). Approximately 18.13 kg of the perchlorate plume is captured in the 100-gpm scenario (Figure 5-5) after 40 years. Approximately 0.42 kg of perchlorate remains in the model after 40 years. A portion (0.73 kg) of the initial perchlorate mass is located downgradient and west of the three extraction wells. This extends the time required to cut off continued migration of the plume to the pond.

Maximum model-predicted influent perchlorate concentrations for the 100-gpm scenario were 6.52, 7.77 and 1.57 µg/L in extraction wells 90EW0001, 90EW0002 and 90EW0003, respectively. The maximum blended concentration for the three wells is 5.51 µg/L. If the flow from these wells were incorporated (blended) into the influent of the current FS-12 treatment train (assuming the current flow rate of 688 gpm remains constant), the maximum predicted concentration is 0.72 µg/L.

5.1.1.5 FS-12 EDB Transport Simulations

The impact of the additional extraction and reinjection on the FS-12 system was modeled using both the recently developed SE Ranges model and the original FS-12 design model, and both the 2003 FS-12 EDB shell developed by CH2M Hill for AFCEE and an FS-12 EDB shell developed by Jacobs for AFCEE. These tools allowed the potential for impacts to be assessed using a range of interpretive constraints and provided an indication of scenario sensitivity in that regard. These tools were used to ensure that the contemplated changes to the wellfield would not have an adverse impact on the FS-12 ETR system performance.

The FS-12 model is a well calibrated and documented model that has not only been used to design and validate FS-12 system performance, but also has been used to optimize the FS-12 system during the last several years. The SE Ranges model has a larger model domain encompassing the SE Ranges and the TOM area, and therefore, allows more accurate simulation of the J-3 plume than the FS-12 model. The model was built with appropriate discretization for transport in the FS-12 area with minimum cell sizes of 30 x 30 feet and layer thickness ranging from 2.3 to 11.7 feet. The EDB transport scenarios evaluated mass capture performance differences between FS-12 operating at average conditions and average conditions with an additional 100 gpm collectively coming from the three currently inactive FS-12 extraction wells to accommodate capture of the J-3 plume.

The 2003 CH2M HILL FS-12 EDB plume shell was mapped into the original FS-12 design model and migrated under average operating conditions and average conditions with 100 gpm from 90EW0001, 90EW0002 and 90EW0003. Current average operating conditions were maintained for the duration of the simulations. Performance of the current FS-12 system and a modified system with wells 90EW0001, 90EW0002 and 90EW0003 operating at a combined flow rate of 100 gpm was compared in terms of EDB mass capture after 5.5 and 20 years of system operation (Table 5-1). The simulation with an additional 100 gpm from the three FS-12 extraction wells captures slightly more mass at 5.5 and 20 years than the average condition alone. The 100-gpm simulation was conducted in the SE Ranges model with similar results (Figure 5-6). Mass capture was nearly identical for the average condition and the average condition with 100 gpm additional (Table 5-1). Although the rate of capture was slightly lower for the average condition from 2005 through 2020 (Figure 5-6), total capture after 20 years of operation was very similar to the anticipated performance of the FS-12 system with J-3 plume extraction. Approximately 99.8 percent of the currently mapped FS-12 EDB mass was captured—consistent with design predictions and goals (Table 5-1). These simulations indicate that J-3 plume extraction using the three inactive FS-12 extraction wells should not adversely impact predicted FS-12 wellfield performance in regard to mass removal and overall remedy time frame.

5.1.2 Ecological Impact Assessment

If a J-3 plume remedial system is designed near FS-12 and Snake Pond, there will be a need to balance aquifer stress, which is required for plume capture, with the minimization of surface water impacts. Groundwater extraction systems exert hydraulic stress on the aquifer in order to develop a zone of influence and capture zone. To minimize potential impacts on surface water bodies due to pumping stress, ecological guidelines were developed by the Technical Review and Evaluation Team (TRET) in 1996 to be used during remedial system design (Technical Review & Evaluation Team 1996). The thresholds include the following:

- no more than 0.5 foot change in water level in recreational ponds relative to ambient conditions (e.g., Snake Pond);
- no more than 0.2 foot change in water level in sensitive ecosystems relative to ambient conditions (this includes vernal pools and wetlands);
- ambient flux through a surface water body cannot be altered by more than 20 percent; and
- no more than 25 percent of the flux through a pond can be treated water.

This amount of drawdown or change in flux characteristics is not an indicator of ecological impacts, nor does it serve as a proxy for ecological impacts. The ecological threshold guidelines were intended to serve as a guideline for design, and as a reference in monitoring, to indicate whether or not greater study and/or mitigation might be required.

In order to estimate the effects of remedial pumping stress on nearby surface water bodies and to quantify the ecological thresholds, the SE Range model is used. In this case the impact of increasing flow rates in the FS-12 wellfield on the ecological thresholds was evaluated using the two flow models for the area: the FS-12 design model and the SE Ranges model. This approach provides a measure of conservatism and serves to test the sensitivity of the threshold criteria to varying flow models. The results from both models indicate that the change in surface water (ambient [no pumping at FS-12] vs. FS-12 average operating conditions plus the additional 100 gpm flow for extraction wells 90EW0001, 90EW0002, and 90EW0003) will be significantly below the threshold for nearby ponds (0.15 foot to 0.12 foot in the FS-12 and SE Ranges models, respectively). No other surface water bodies in the vicinity of FS-12 were identified as sensitive ecosystems during the design of the FS-12 system, and therefore, no other water bodies were evaluated. Both of the flow models indicate the percentage of pond flux that is treated water is less than 5 percent of the total flux of the pond, well below the 25 percent threshold. The percent change in pond flux (ambient vs. active FS-12 operations plus the additional 100 gpm flow for extraction wells 90EW0001, 90EW0002, and 90EW0003) was near 20 percent in some of the FS-12 and SE Ranges model scenarios. Additional simulations were conducted to determine if modifying the reinjection distribution of the FS-12 wells would improve the change in flux through the pond, with some success. Evaluation of adherence to the ecological thresholds will need to be considered during any final design modifications and as both systems are optimized in the future.

5.2 TREATMENT SYSTEM BASIS OF DESIGN

This section presents the basis of design for the J-3 plume treatment system. In addition to achieving the remedial action objectives and treatment standards, the selected treatment technology will be designed to minimize (1) total installed cost, (2) physical impacts, such as relocating piping, wiring, and equipment within the existing FS-12 facility, (3) impacts on FS-12 operations, (4) impacts on the property owner and Camp Good News activities, and (5) training requirements for O&M personnel. To support these objectives, existing FS-12 plant specifications for equipment, piping, and instrumentation, as well as lessons learned from other MMR treatment systems, should be incorporated into the J-3 Range design to the maximum extent possible.

5.2.1 Contaminants of Concern and Influent Concentrations

Based on the aforementioned preliminary wellfield scenario testing, the maximum influent concentration of perchlorate from the three extraction wells is expected to approach 6 µg/L, with the maximum from any one extraction well approaching 8 µg/L. Although the maximum detected perchlorate concentration within the plume is much higher (311 µg/L), influent concentrations in extraction wells are typically much lower because the extraction wells are screened across both low and high concentration areas within plumes and the well captures low concentration areas outside the core of the plume. They inevitably capture some clean water that mixes with higher concentration water from discreet intervals along the extraction screen. The maximum influent concentration of RDX from the three extraction wells is expected to approach 1 µg/L, with the maximum from any one extraction well approaching 2 µg/L. Predicted average annual influent concentrations for perchlorate and RDX for the anticipated life of extraction well operation are shown in Figure 5-7. The concentrations are modeled over a 40-year pumping period assuming flow rates of 50 gpm, 25 gpm, and 25 gpm for extraction wells 90EW0001, 90EW0002, and 90EW0003, respectively.

5.2.2 Treatment System Media Change-Out

The J-3 plume treatment system will require the use of treatment media (carbon, resin, etc.) that will periodically require replacement or change-out as the capacity for effective treatment within an individual treatment vessel becomes exhausted. The change-out criteria will likely be based on breakthrough of COCs above a predetermined threshold concentration, at the exit end of the lead vessel (i.e., first vessel) in a treatment system configured with multiple treatment vessels in series.

5.2.3 Future Flow Rate Considerations

To assess how potential future remedial actions may impact the RRA treatment train design transport simulations were also conducted to assess likely influent contaminant characteristics and flow rates if an additional in-plume well (located upgradient of extraction well 90EW0001) is added to the wellfield. Modeling of a hypothetical wellfield that incorporates one additional in-plume extraction well pumping from an observed high concentration area of the plume was performed. Based on a total influent flow rate of 150 gpm, the maximum influent concentration of perchlorate from all four extraction wells is expected to approach 6 µg/L, with the maximum from any one extraction well near 15 µg/L. The maximum influent concentration of RDX is expected to be approximately 3 µg/L, with the maximum from any one extraction well approaching 8 µg/L. The concentrations are based on a 20-year pumping period assuming flow rates of 50 gpm, 50 gpm, 25 gpm, and 25 gpm for extraction wells 90EW0033 (the in-plume well), 90EW0001, 90EW0002, and 90EW0003, respectively. These flow rates and influent concentrations are expected to be within the operating considerations of the proposed treatment technology.

It is noted that future remedial action requirements will not be determined until completion of the groundwater report and feasibility study. It is not known at this time if additional remedial actions are warranted or whether the proposed RRA treatment train would be utilized.

5.2.4 Biofouling Potential

A potential limiting factor on the treatment system is the possibility of biofouling. Predicting the potential for biofouling has been a challenging task for many treatment systems at MMR. The potential for biofouling problems to affect the extraction and treatment of the J-3 Range plume should be further evaluated during detailed design. Based on experience with the design and operation of other MMR plumes that exhibit biofouling, it is assumed that the treatment process can be configured to address biofouling, if necessary.

A definitive method for predicting biofouling conditions from monitoring well and influent data has not been possible at most MMR treatment facilities due to:

- The action of pumping groundwater from extraction wells, the mixing of extracted water from several wells, and the groundwater treatment process may significantly change the characteristics of the extracted groundwater and/or the aggressiveness of the microbes in the groundwater.
- Parameters thought to be good predictors of biofouling potential (i.e., iron, manganese, and total suspended solids) have not been found to consistently correlate with actual biofouling at most treatment systems at the MMR.
- Wide variations in fouling response/behavior have been encountered within relatively short distances (adjacent wells) at MMR.

As a comparison and preliminary indicator of the potential for biofouling at J-3, Table 5-2 provides a statistical comparison of physicochemical parameters for the J-3 and FS-12 plumes. The operating history of the FS-12 treatment system indicates that approximately 10 percent of the extraction wells exhibit significant biofouling. Data used to characterize the groundwater at FS-12 and the J-3 Range were compiled from the VIEW database and from data provided by AMEC. The FS-12 and J-3 data sets consisted of field parameters in groundwater collected from the years 2002 and 2003. The FS-12 data set included groundwater samples collected from 112 wells located within the capture zone as defined in the Final Fuel Spill-12 2001 Annual System Performance and Ecological Impact Monitoring Report (AFCEE 2001) and downgradient of the source area (Greenway Road). The J-3 dataset included groundwater samples collected from 147 wells located outside the FS-12 capture zone and/or upgradient of the FS-12 source area (Greenway Road).

The statistical analysis of the parameters pH, temperature, dissolved oxygen, oxidation-reduction potential, specific conductance, and turbidity shows a significant difference between the FS-12 groundwater and the J-3 Range groundwater. In many cases, the differences show that the quality of the J-3 Range groundwater is better than the FS-12 groundwater. This is likely due, in part, to the biodegradation of organic compounds in the FS-12 plume. Most notable is the higher dissolved oxygen content in the J-3 Range groundwater (9.58 mg/L) compared to the FS-12 groundwater (7.91 mg/L). Higher specific conductance in the FS-12 groundwater could also be related to biological activity that tends to liberate soluble metals from the matrix to the groundwater. There is also significantly lower turbidity in the J-3 Range groundwater, which would mean minimal impact to the FS-12 treatment system from solids. The lower pH and the lower oxidation-reduction potential in the J-3 Range groundwater are not easily explained, but could be due to differences in the geology of the two groundwater components, specifically the content of carbonates and other minerals. Differences in parameter measurements could be related to equipment or technique variability.

Other data to be considered in evaluating biofouling potential for the J-3 plume treatment system (e.g., total organic carbon (TOC), iron content, etc.) are presented in Table 5-3. The data presented in Table 5-3 represent all available data collected within 250 meters of the J-3 Range, so variability in results is to be expected. The maximum detected results for TOC and iron, if considered alone, would indicate that there is potential for biofouling, however the average results for these analytes are low.

In conclusion, although statistically different, the differences between FS-12 and J-3 Range groundwater should not impose a negative impact on the FS-12 treatment system or on the ability to effectively treat the J-3 plume contaminants. It is noted, that the more significant biofouling problems at various treatment facilities all have a common denominator. The organic content and fuel component concentrations provide significant food to existing bacteria. In summary, preliminary analysis does not suggest biofouling potential and indicates generally good quality water in the J-3 area. The potential for biofouling at the J-3 Range should be further evaluated during detailed design; however, allowances can be made in the treatment system configuration so that biofouling can be treated should it impede operations.

5.3 TECHNOLOGY EVALUATION

This section presents a summary of available remedial technologies to treat perchlorate and RDX and assesses the feasibility of using existing infrastructure from the FS-12 facility to treat the J-3 plume. Viable treatment methods are identified based on site characteristics and design bases. The recommended treatment alternative is then determined by comparing the relative capital cost and the integration of each viable alternative into the FS-12 facility.

Remedial technologies were identified based on a review of technology literature, vendor information, and studies. The treatment technologies were grouped into destructive and physical removal processes, and then evaluated for applicability to the J-3 Range based on past performance in similar applications.

5.3.1 Demo 1 Groundwater Operable Unit Evaluations

Since the site characteristics (i.e., COCs, design flow rates, and hydrogeology) for the Demo 1 Groundwater Operable Unit are similar to those of the J-3 Range, the treatment alternatives identified and evaluated for Demo 1 are directly applicable to the J-3 Range evaluation, although the final recommendations may differ. The draft report, *IAGWSP Technical Team Memorandum 01-17 Feasibility Study Report, Demo 1 Groundwater Operable Unit* (AMEC 2001d), was included in the treatment technology literature review. The COCs for the Demo 1 feasibility study (FS) were RDX, TNT, HMX, 2A-DNT, 4A-DNT, 2,4-DNT, and perchlorate. The flow rates evaluated in the Demo 1 Draft FS were in the range of 100 gpm.

The same basic technology types evaluated in the Demo 1 initial alternative screening are also evaluated for the J-3 Range; however, the treatment alternatives presented in the

Demo 1 Draft FS were refined as a result of EPA comments. Although it was retained after the initial alternative screening, ion exchange with secondary GAC treatment was not included as a recommended alternative in the Demo 1 Draft FS. The two treatment alternatives most highly recommended for the Demo 1 Groundwater Operable Unit were both based on extraction coupled with fluidized bed reactor (FBR)/GAC treatment, although other viable, but more costly, in-situ treatment alternatives were also considered in the Demo 1 Draft FS report.

5.3.2 Bench-Scale Studies

In addition to the Demo 1 Draft FS, the Final Innovative Technology Evaluation Groundwater Treatability Study Summary: Fluidized Bed Reactor Study #2 (AMEC 2003a), the Innovative Technology Evaluation Groundwater Treatability Study Summary: Rapid Small Scale Column Tests #1 (AMEC 2003d), and Innovative Technology Evaluation Groundwater Treatability Study Summary: Rapid Small Scale Column Tests #2 (AMEC 2004) were reviewed for treatment alternatives applicable to the J-3 Range. These studies tested treatment effectiveness for the respective technologies on groundwater containing perchlorate at concentrations in the range of 2 to 6 µg/L, which is similar to the expected concentrations for the J-3 Range. The results of these studies indicate that treatment of perchlorate-contaminated groundwater using FBR, tailored GAC, and non-tailored GAC is viable. Tailored GAC was found to have a minimum anticipated bed life around 77,000 bed volumes (BVs) and a maximum anticipated bed life around 270,000 BVs for perchlorate removal. Non-tailored GAC was found to have a minimum anticipated bed life around 20,000 BVs and a maximum anticipated bed life around 40,000 BVs, for perchlorate removal. Non-tailored GAC was also found to be very effective at removing RDX, with an estimated bed life around 300,000 BV. These AMEC studies also acknowledge ion exchange as being a viable treatment alternative. Further testing is being performed and will be considered in the detailed design of the J-3 Range treatment system.

5.3.3 Description of Current Technologies

The treatment technologies currently available for application to the J-3 plume are described below, and are categorized as either destructive or physical removal processes. The effectiveness of each technology for treating perchlorate and RDX-contaminated groundwater is described, if known, based on results presented in available literature.

- Destructive Processes:
    - biological reduction;
    - chemical reduction;
    - electrochemical reduction; and
    - oxidation.

- Physical Removal Processes:
    - carbon adsorption;
    - ion exchange;
    - membrane filtration (reverse osmosis [RO] & nanofiltration); and
    - electrodialysis.

The optimum treatment technology for a given perchlorate or RDX application is dependent on several factors, including concentration, the presence and concentration of co-contaminants, and other water quality parameters (e.g., pH, alkalinity, natural organic matter, total dissolved solids, metals.). The presence of indigenous perchlorate-reducing microbes (PRM), and substances inhibitory to PRM activity will also influence perchlorate treatment technology effectiveness.

5.3.3.1 Destructive Processes

Biological Reduction: Biological reduction is a promising treatment technology for perchlorate removal. In the biological treatment process, microbes destroy perchlorate by converting the perchlorate ion to oxygen and chloride. In most cases, nutrients are added to sustain the microbes. Several types of microorganisms are capable of using perchlorate as an oxidant (electron acceptor) for metabolism. It is generally accepted that these microbes possess a reductase (an enzyme) that allows them to lower the activation energy of perchlorate reduction and thereby make use of the energy for cellular respiration. The FBR is an effective biological method for treating perchlorate. A full scale FBR system designed to treat up to 4,000 gal/min of groundwater contaminated with perchlorate is currently in operation in California (Hatzinger et al. 2000). The system has demonstrated reduction of perchlorate from 400 mg/L in the contaminated groundwater to the MDL of the referenced facility (0.004 mg/L or 4 ppb).

Biodegradation has also been proven as an effective method of treating RDX-contaminated water. Biodegradation transforms the RDX to harmless end products (i.e., carbon dioxide, ammonia, methane and some biomass). The anaerobic biological GAC-FBR is a fixed film, biological treatment system utilizing GAC as a support media upon which the bacteria attach and grow. The contaminated water to be treated is pumped upwards through a bed of GAC, fluidizing the media. Ethanol or acetic acid, simple organic substrates (electron donor) are used for biomass growth. Biodegradation of the added organic substrate (i.e., ethanol/acetic acid) is achieved by a thin film of microorganisms that coats each particle. This biofilm converts the adsorbed organic carbon mass to harmless end products. The high biomass concentrations achieved in the fluidized bed result in high removal efficiencies.

<u>Chemical Reduction</u>: While perchlorate is thermodynamically a strong oxidizing agent, its reduction is generally very slow, rendering common reducing agents ineffective. However, recent studies involving chemical reduction using zero valence metals for perchlorate and RDX in groundwater are promising, and chemical reduction may emerge as a viable treatment option in the future.

<u>Electrochemical Reduction</u>: Perchlorate can be reduced to chloride by using an electric current applied directly to the water by a cathode at high potential. There are several limitations with electrochemical reduction, most notably, the time required to get ions to the electrode surface from the bulk water as well as the time required for them to associate with the surface. While this technology is well established for such industrial processes as metal electroplating or brine electrolysis, it has not been implemented in treating perchlorate-contaminated water. No data were found for treating RDX contaminated water using electrochemical reduction.

<u>Oxidation</u>: The pilot study *Groundwater Circulation Wells Using Innovative Treatment Systems* (Elmore and Graff 2000), describes the effective treatment of RDX-contaminated groundwater using ultraviolet (UV) photolysis. The influent concentrations have ranged from around 5 µg/L to 78 µg/L. The UV treatment method reduced RDX concentration in effluent

samples to less than the detection limits. Ultraviolet degradation, in combination with ozone or hydrogen peroxide, may provide a means of destroying RDX contaminated water in an efficient and economic manner. Given the oxidation state of perchlorate, chemical oxidation is not a feasible means of destroying perchlorate in groundwater.

5.3.3.2 Physical Removal Processes

Carbon Adsorption: In recent years, there has been an increase in bench-scale and pilot-scale testing for removing perchlorate with GAC, although definitive full-scale data are not yet available. GAC is a proven method for adsorbing RDX from groundwater. Although effective on a variety of contaminants, adsorption simply transfers contaminants from water to the surface of the GAC and provides no permanent treatment or destruction of the contaminants. Since GAC has a finite adsorption capacity, the carbon must be periodically backwashed and eventually replaced. Most of the recent GAC/perchlorate studies involve carbons modified with monomer and polymer formulations, also known as tailored GAC. Using tailored carbons specific to the contaminants to be removed can enhance removal efficiency and bed life. Discussions with U.S. Filter (U.S. Filter 2003) indicate that the economics for tailored carbon begins to become unfavorable for perchlorate concentrations above 15 µg/L.

As described in Section 5.3.2, the Impact Area Groundwater Study Program Rapid Small Scale Columns Tests #1 and #2 have shown very favorable results using tailored GAC for treating low levels of perchlorate-contaminated groundwater. These studies were based on groundwater collected at Camp Edwards, MMR. Tailored GAC performance in removal of perchlorate in these tests yielded 77,000 BVs to 270,000 BVs before breakthrough. Results from non-tailored GAC tests indicate an anticipated bed life of 300,000 BV for RDX removal. The studies suggest that even higher bed lives can be achieved. Although very favorable, the results from the RSSCT studies were obtained while operating the test columns in up flow mode, not consistent with a down flow orientation that most full-scale GAC systems operate (ASTM 2003). In summary, although very positive, the results of the RSSCT GAC studies should be applied in a conservative manner for predicting full-scale system performance.

Ion Exchange: With ion exchange, perchlorate is replaced by an innocuous anion, usually chloride. An ion exchange system typically consists of a pretreatment/filtration section, an initial ion exchange section, and a final ion exchange section. Water flows through ion exchange columns that contain a resin latent with the replacement ion. Due to relative concentration differences of the two ions in the resin, the perchlorate switches places with the other ion, which is then released into the water. Eventually, the resin reaches an equilibrium concentration where no more perchlorate can be extracted from the water, and the resin must be regenerated or disposed of. If the resin is regenerated, the regenerant solution contains a high concentration of perchlorate and must be disposed of properly. In general, the cost of selective resins for removal of perchlorate is high, compared to other media such as activated carbon. Recently, the cost of non-regenerable resins has decreased significantly, making them more economically attractive. Some examples of ion exchange resins specifically tailored for non-regenerative, low-perchlorate concentration applications are marketed under the trade names DOWEX 1 (Dow Chemical Company), CalRes 2101 (Calgon Carbon Corporation), and PWA2 (U.S. Filter). Ion exchange system performance and longevity are affected by other species present in the influent, specifically suspended solids, iron, manganese, nitrates, and sulfates. In San Gabriel Valley, bench and pilot scale studies have demonstrated that ion exchange systems can reliably reduce perchlorate concentrations in groundwater from approximately 75 µg/L to less than 4 µg/L (EPA 1999). In addition, U.S. Filter has installed several ion exchange systems throughout the country for treating low levels of perchlorate (less than 10 µg/L) to less than 1 µg/L. Currently, a pilot study is being performed at the Pew Road site at MMR. The results of this study will be reviewed for the J-3 plume treatment system to better estimate bed life and resin replacement costs for detailed engineering.

As discussed with perchlorate treatment, RDX can be removed from groundwater using ion exchange; however, RDX does not ionize as readily as perchlorate, so a different resin would be required for its removal. A feasible method for treating both perchlorate and RDX using ion exchange would require removing perchlorate first using a series of ion exchange columns, then removing RDX and polishing with GAC adsorbers. The contaminant concentration and flow rate, as well as the concentration of other species such as suspended solids, iron, manganese, nitrates, and sulfates, must be considered when evaluating this technology for RDX treatment. Test data for RDX removal using ion exchange would be required to determine bed life and resin replacement costs during subsequent engineering evaluations, however given the low concentrations of RDX at the J-3 Range, removal of RDX using standard GAC treatment as a polishing step is a much more cost effective approach.

Membrane Filtration: This includes such techniques as RO and nanofiltration. Contaminated water is forced through a semi-porous polymer membrane. Dissolved salts are unable to penetrate the membrane. The filtrate (or permeate) is almost completely deionized. The concentrate contains all rejected dissolved matter, including the perchlorate and RDX. The volume of the reject stream is a function of the concentration differential between the permeate and inlet streams. The reject stream can be a significant volume that requires treatment and disposal. In addition, RO and nanofiltration typically require pretreatment and high operating pressures (200 to 1000 psig). RO and nanofiltration were tested by researchers at the Metropolitan Water District of Southern California (MWDSC 1999-2000) and shown to be effective in removing perchlorate, but they are likely to be much more expensive to operate than ion exchange.

Electrodialysis: In electrodialysis, contaminated water is passed through channels of alternating membranes permeable to either anions or cations, while being exposed to an electric field. This produces alternate channels of nearly deionized water and concentrated wastewater. Work in this area is ongoing and more data are needed before this technique can be applied full-scale.

5.4 TREATMENT ALTERNATIVES

After review of available remedial technologies, consideration of site characteristics, and preliminary design objectives, three treatment alternatives were conceptually developed and are presented in the following sections. The viable treatment alternatives for the J-3 plume include FBR, GAC, and ion exchange. Initially, FBR was evaluated as the sole treatment alternative; however, after additional data were evaluated and discussed among USACE, AFCEE, ECC, and Jacobs, GAC and ion exchange were added as viable options for consideration. This insight was based in part on the reports *Innovative Technology Evaluation Groundwater Treatability Study Summary: Rapid Small Scale Column Test #1*, (AMEC 2003d), *Technology Evaluation Rapid Small Scale Column Test Study Including Report for Study #1 (And Addendum)* (AMEC 2003e), and *Innovative Technology Evaluation Groundwater Treatability Study Summary: Rapid Small Scale Column Test #2 (AMEC 2004)*.

Assessment of the potential use of the existing FS-12 treatment facility was developed as the treatment technologies were reviewed. Alternatives that involved combining the influent streams for the J-3 plume and FS-12 treatment systems were eliminated based on discussions among USACE, AFCEE, ECC, and Jacobs and limitations regarding monitoring and treatment system performance assessment. Monitoring for contaminant removal would not be practical or effective for the J-3 plume in the event that the influent streams are combined.

The option to utilize the existing FS-12 GAC system was eliminated as a viable scenario due to (1) operational problems that would potentially occur if one system was taken off-line, (2) the potential to reduce carbon utilization in the current GAC system, and (3) the potential for the GAC system not to function optimally at reduced flow rates (100 gpm) after the FS-12 wellfield is decommissioned (the hydraulic minimum flow rates for the current FS-12 GAC system is significantly greater then 100 gpm). The preferred conceptual design is to decouple the influent piping and treatment components of the systems. Operationally, the new system required for the J-3 plume could potentially utilize the existing backwash and effluent system. This would include the backwash pump to be utilized for backwashing the unit(s) as required, sedimentation tank for containment of the backwash sludge, the effluent holding tank for holding the treated water before discharge to the effluent system, the effluent pump, and effluent infiltration system.

The option to design and build a new stand-alone facility for the J-3 plume was eliminated. It was deemed most cost effective to use available space within the footprint of the existing FS-12 facility. The FS-12 facility has sufficient available space to treat 150 to 250 gpm, depending on the technology installed.

5.4.1 Fluidized Bed Reactor

The FBR alternative considered most feasible for design and interface with the FS-12 treatment facility is FBR/GAC treatment located within the FS-12 facility with a new influent line from the extraction wells. The FBR effluent would be routed to a new dedicated set of GACs located in the FS-12 facility. Treated discharge would be routed to the FS-12 effluent line or effluent tank.

This FBR option requires the design of a system that does not tie-in to the existing FS-12 system, except for interface with the existing effluent system, after treatment of the water. The current footprint of the FS-12 building is utilized for this option; however, some obsolete equipment would be removed to provide adequate space. This alternative is viable. Figure 5-8 shows the process flow diagram for the FBR treatment system alternative.

5.4.2 Granular Activated Carbon

The carbon adsorption alternative is comprised of a series of GAC vessels, with a new influent line from the extraction wells. The treated effluent would be routed to the FS-12 effluent tank or effluent line, then to the existing reinjection system.

This alternative requires the design of a system that does not tie-in to the existing FS-12 system, with the exception of interface with the existing backwash and effluent systems, after treatment of the water. The GAC system will be comprised of two vessels (tailored GAC) for perchlorate removal and two vessels (non-tailored GAC) for RDX removal. The GAC vessels may have to be periodically backwashed if fouling induces excessive pressure drop or plugging. Any potential untreated groundwater in the headspace of the GAC vessels will be backwashed along with the treated backwash water to the sedimentation tank. This volume of untreated water is insignificant and can be treated along with the sedimentation tank decant by the FS-12 facility treatment system.

The current footprint of the FS-12 building is utilized with minimal impacts. The GAC vessels will fit within the maintenance storage area. This alternative is viable. Figure 5-9 shows the process flow diagram for the GAC treatment system alternative.

5.4.3. Ion Exchange

This alternative is comprised of a set of prefilters followed by two ion exchange columns for perchlorate removal and two carbon vessels for RDX removal, with a new influent line from the extraction wells. The treated effluent is routed to the FS-12 effluent tank or effluent line, then to the existing reinjection system.

This alternative requires the design of a system that does not tie-in to the existing FS-12 system with the exception of interface with the existing backwash and effluent systems after treatment of the water. The vessels may have to be periodically backwashed if fouling induces excessive pressure drop or plugging. Any potential untreated groundwater in the headspace of the vessels will be backwashed along with the treated backwash water to the sedimentation tank. This volume of untreated water is insignificant and can be treated along with the sedimentation tank decant by the FS-12 facility treatment system.

The current footprint of the FS-12 building is utilized with minimal impacts. The ion exchange and carbon vessels should fit within the maintenance storage area. This alternative is viable. Figure 5-10 shows the process flow diagram for the ion exchange treatment system alternative.

5.4.4 Comparison of Capital Costs

A preliminary relative capital cost comparison was developed for the FBR, GAC, and ion exchange alternatives. Equipment location and installation was not a factor for the cost basis. Only the cost of capital equipment and annual media replacement associated directly with the treatment technology itself was included. For the GAC and ion exchange options, two primary vessels were assumed for perchlorate removal, and two polishing vessels were assumed for RDX removal. The cost of other capital items such as extraction wells, extraction well and influent header piping, pumps, controls, accessories, and tie-ins are anticipated to be the same regardless of the treatment technology selected, and therefore are not quantified as part of this analysis. In addition, the capital cost comparison does not include engineering, design, management, or O&M associated costs (i.e., chemical reagents, PPE, etc.).

The relative capital cost comparison is contained in Table 5-4. An analysis of the capital cost comparison is provided in Section 5.4.5 in conjunction with the determination of the recommended treatment alternative.

5.4.5 Recommended Treatment Alternative

This section summarizes the basis for the recommended treatment alternative based on the capital cost comparison, feasibility of integration with FS-12 infrastructure, and regulatory considerations.

The treatment alternatives with the lowest capital costs are the non-tailored and tailored GAC options. This option is similar to existing O&M operations at the FS-12 facility. Therefore, it is likely that O&M impacts and operator training requirements will be similar. Figure 5-11 shows the general arrangement for the proposed GAC treatment system and associated components. Note that for the given footprint, it is estimated that the maximum flow for the GAC treatment system is limited to approximately 200 to 250 gpm. This flow rate capacity is significantly greater than the flow rate required to capture the plume (100 gpm) and greater than higher flow rate scenarios (150 gpm) tested to assess hypothetical final action pumping requirements.

Ion exchange is the treatment alternative with the next lowest capital cost. It should be emphasized that ion exchange alone will not remove both perchlorate and RDX using a single resin. A secondary set of GAC adsorbers would be required to capture RDX. Although the capital cost for the ion exchange (with secondary GAC adsorbers) option is more than that of non-tailored and tailored GAC, the estimated annual media replacement cost for the ion exchange option falls between that of the non-tailored and tailored GAC options. This option is not as similar to existing O&M operations as the GAC option, therefore it is likely that O&M requirements (e.g., operator training, inspections, etc.) would be greater. Figure 5-12 shows the general arrangement for an ion exchange treatment system and associated components. Note that for the given footprint, it is estimated that the maximum flow for the ion exchange treatment system is limited to approximately 150 gpm. This flow rate/capacity is greater than the flow rate required to capture the plume (100 gpm) and equivalent to the higher flow rate scenarios (150 gpm) tested to assess hypothetical final action pumping requirements.

FBR has the highest capital cost of all the feasible treatment technologies. It is also expected to require much more floor space (1,000 square feet versus 500 square feet) in the FS-12 building than the GAC or ion exchange options. FBR is not similar to the existing operations at FS-12. O&M and training impacts will be significantly higher compared to GAC and ion exchange. These capital cost, footprint, and O&M requirements eliminate FBR from further consideration.

The preliminary general arrangements show how the proposed equipment for the GAC and ion exchange options would be located within the existing FS-12 treatment facility. The proposed location for either treatment option is viable. In addition, it is anticipated that interference/routing issues for both options will be minimal based on preliminary piping and controls routing reviews.

In summary, tailored carbon and ion exchange are recommended as viable treatment technologies for the J-3 Range plume. Both tailored GAC and ion exchange are currently being evaluated in a pilot study located at the Pew Road site. The results of the Pew Road study will be reviewed and considered in the final design for the J-3 plume treatment system. The exact treatment media will be finalized after reviewing results from the Pew Road study, however it is currently recommended that tailored GAC be selected as the perchlorate treatment technology followed by non-tailored GAC for RDX treatment for the J-3 plume. The Pew Road results are expected to be available in September 2004.

5.5 DESCRIPTION OF TREATMENT PROCESS

GAC adsorption, using tailored carbon for perchlorate removal and non-tailored carbon for RDX removal, is anticipated to reduce contaminant concentrations to required treatment levels. The treatment system would share the FS-12 backwash equipment and effluent system, so there are no impacts to the FS-12 extraction and treatment systems.

The system can be automated and requires routine inspection similar to the current plant operations at MMR. Some additional time is required by the operators to inspect, monitor, perform maintenance, and coordinate media deliveries.

The following is a partial list of design issues for the J-3 rapid response action plan that will be addressed during the design phase of the project:

- carbon and/or resin formulations (review of Pew Road pilot study);
- characterization of spent media and sludge for determination of appropriate means of treatment and disposal. It is anticipated that this will incorporate results from the Pew Road Study;
- personnel egress and access to the J-3 and FS-12 treatment systems;
- detailed FS-12 system interface issues and processing (Backwash, effluent tank), etc; and
- O&M media change-out procedures.

5.5.1 Pretreatment

The J-3 plume influent will be pumped from the extraction wells to the treatment system inside the FS-12 facility. GAC systems at MMR have not historically required prefiltration, so prefiltering of the J-3 plume influent is not envisioned currently, however prefilters could be incorporated into the design to reduce carbon fouling if necessary. In addition, provisions will be made in the design to accommodate connection points for chemical addition should it be required in the future (e.g., bleach injection for treating biofouling). The pretreatment requirements will be determined prior to detailed design by evaluating groundwater quality data for the J-3 Plume.

5.5.2 Perchlorate Removal System

After pretreatment, the influent will be piped to the first set of GAC vessels that contain carbon tailored to remove perchlorate. The perchlorate GAC vessels will consist of two vessels arranged in series, each being approximately 3 to 4 feet in diameter and 6 to 7 feet tall, based on the design flow rate of 100 gpm, and will be pressure rated according to the design system pressure. The vessels will be filled with a carbon manufactured specifically for the capture of perchlorate. The GAC system will be equipped with the necessary interconnecting piping, valves, gauges, and pressure relief devices. The vessels may be skid mounted or bolted directly to the FS-12 facility pad.

5.5.3 RDX Removal System

After removal of perchlorate from the influent by the first set of GAC vessels, a second set of vessels containing non-tailored carbon will remove the trace amounts of RDX present in the J-3 groundwater to complete the treatment process. The size and rating of the second set of GAC vessels will be similar to those of the first set. The second set of GAC vessels will also be equipped with the necessary interconnecting piping, valves, gauges, and pressure relief devices. The vessels may be skid mounted or bolted directly to the FS-12 facility pad.

5.6 PIPING

This section describes the piping systems that will be used to convey the extracted and treated groundwater for the J-3 Range. Piping for conveying extracted groundwater from the extraction wells to the treatment system will be buried below the ground surface. The treated groundwater (effluent) will be discharged using the existing FS-12 reinjection system. The following sections describe the influent and effluent piping systems, and present an evaluation of potential impacts to the FS-12 facility.

5.6.1 Influent Piping

Because the influent streams for FS-12 and the J-3 plume will remain separate, there are no hydraulic impacts to the current FS-12 extraction well system. Approximately 1,750 feet of new pipe will be installed from the three existing, unused FS-12 extraction wells (90EW0001 through 90EW0003) to the FS-12 facility. The influent header is assumed to run parallel to the existing extraction well influent header for the FS-12 facility. The new extraction well piping is expected to be approximately 2-inches in diameter. The influent header piping to the FS-12 plant is expected to be approximately 3-inches in diameter. Both the extraction well and influent header piping would be constructed from HDPE.

5.6.2 Effluent Piping

The FS-12 effluent system header piping consists of 6-inch and 8-inch polyvinyl chloride. The length of header piping from the FS-12 facility to the furthest extraction well is approximately 5,200 feet. The reinjection header piping is approximately 6,100 linear feet of pipe.

The treated groundwater from the J-3 plume treatment system will add approximately 100 gpm to the FS-12 effluent system. This results in a combined total flow of approximately 780 gpm for the effluent system.

The effluent header and recently upgraded effluent pump system have demonstrated the capability to distribute the flow resulting from a plant influent flow rate of 780 gpm during normal operations, so no changes to the existing effluent system are necessary. The existing FS-12 effluent pump and piping system is capable of discharging an estimated 900 gpm according to the hydraulic model developed for the FS-12 system, although this added flow would have to be distributed appropriately across the various reinjection wells. The resulting treated water could be discharged via either the existing effluent holding tank or to the existing effluent header system in the event the FS-12 treatment system is offline. The current effluent system contains the necessary flow control valves for flow distribution.

There is no significant impact expected to the current FS-12 effluent system at a J-3 plume effluent flow of 100 gpm. Potential impacts to the effluent system will require re-evaluation should the flow rate for the J-3 plume significantly exceed 100 gpm. It is noted, AFCEE is in the process of assessing FS-12 wellfield optimization opportunities. It is possible that flow rates will be further reduced at FS-12 in the near term providing additional effluent system capacity.

5.7 TREATMENT SYSTEM MONITORING AND MAINTENANCE

The J-3 plume treatment system will be monitored on a regularly scheduled basis. The J-3 plume treatment system will include appropriate instrumentation, alarms, and control interlocks to permit continuous operation. System parameters, including flow, pressure, and differential pressure will be monitored in addition to sampling for contaminant concentrations for determining treatment efficiency and media change-out (see Section 7.0). System sampling will be conducted on a frequent basis during, and immediately following start-up. After operation of the treatment system has been established, system sampling will be reduced in a graduated scheme (i.e., weekly, bi-weekly, then monthly). An O&M procedure will be developed to include the requirements and schedule for system monitoring and maintenance of the J-3 plume treatment system. The various stages of the treatment system (before, intermediate, and after) will be sampled according to the O&M schedule. The treatment media will be replaced when perchlorate and/or RDX breakthrough the lead vessel.

5.8 BUILDING (FS-12 FACILITY)

The FS-12 treatment facility has approximately 16,000 square feet of floor space. Much of the floor space is occupied by FS-12 treatment system equipment, which consists of four 75,000-pound greensand filters, six 20,000-pound carbon adsorption vessels, one 23,000-gallon influent tank, one 23,000-gallon effluent tank, one 19,000-gallon sedimentation tank, UV/oxidation and chemical feed systems, and various transfer pumps. The treatment system flow rate is currently held at 688 gpm, but has demonstrated a flow rate of 800 gpm. The facility contains access aisles for maintenance and truck access around the equipment, and a 500 square foot maintenance storage area which could potentially be used for the new J-3 Range treatment system.

5.9 REINJECTION SYSTEM

The modeling conducted to develop the conceptual wellfield (Section 5.1 and Appendix B) indicates there should be no problem with reinjecting the treated water using the existing reinjection wells. No exceedances of the ecological thresholds are expected. However, this will need to be verified as part of the final wellfield design.

The method of recharge is based on the desire to utilize the existing effluent and reinjection system at the FS-12 facility. Well reinjection is a common and proven technique for returning treated groundwater to the aquifer at MMR.

The FS-12 reinjection system consists of 22 reinjection wells (currently there are 17 reinjection wells operating). The nominal flow rate for each reinjection well ranges from 20 to 90 gpm.

5.10 REMEDIATION WASTE AND SECONDARY WASTE MANAGEMENT

Waste that is generated as a result of J-3 Range remedial activities can be categorized as either remediation waste or secondary waste. Remediation waste is any uncontainerized material, media, or debris that is contaminated. The only remediation waste that is expected to be generated by the J-3 RRA project is extracted groundwater, which will be treated. It is not anticipated that soil cuttings resulting from below ground pipe installation will be contaminated. If contaminated soil in encountered, an excavated soil management plan will be developed.

Secondary waste includes containerized waste that may or may not be contaminated. Examples of secondary waste include spent treatment media (resin, activated carbon, etc.), waste sludge, and personal protective equipment (PPE). Secondary wastes are typically stored and transported in drums, boxes, or tanker truck. Spent treatment media will undergo waste characterization to determine the appropriate means of treatment and disposal. Waste sludge and PPE that are generated by J-3 Range ETR system activities will also be characterized and disposed of according to the existing waste management program for the FS-12 facility.

6.0 ADDITIONAL DATA REQUIREMENTS FOR FINAL DESIGN

This section identifies data requirements and upcoming studies that are necessary to complete the detailed design of the J-3 Range ETR system.

6.1 PEW ROAD STUDIES

Results of pilot scale testing at the Pew Road location should become available before the end of September 2004. Results from these tests will be evaluated for application to, and optimization of, the J-3 Range ETR system design. The detailed design effort will already be underway when the Pew Road results become available, so potential impacts to the design effort cannot be defined currently.

6.2 INITIAL DATA REQUIREMENTS

Recent modeling of the J-3 Plume indicates the predicted flow field can be moderately sensitive to varying model parameters such as hydraulic conductivities, TOM position, and boundary conditions. Available water level data sets collected in this area are sparse or incomplete in the vicinity of the north side of Snake Pond and north to the source area. To reduce the uncertainty associated with the model-predicted and observed trajectories and better refine the required flow rate and flow rate distribution, a synoptic water level measurement study is proposed. Results of the synoptic water level study will be used to recalibrate the version of the SE Range model that will be used for final rapid response action wellfield design. The complete scope of the proposed synoptic water level study will be provided to the regulatory agencies prior to conducting the event.

Following are data needs and investigative activities that are required to complete detailed design of the J-3 Range ETR system:

- survey of existing monitoring wells;
- synoptic water level study;
- acquisition of civil site survey data;
- determination/verification of COCs through ongoing LTGM and planned aquifer profile boring installation;

- collecting and analyzing groundwater quality data specific to the J-3 plume (nitrates, sulfates, TDS, iron, etc.) for predicting treatment system effectiveness, break-through, and pretreatment requirements; and
- evaluation of waste treatment and disposal.

6.3 DATA REQUIREMENTS FOR FINAL DESIGN

After the hydraulic data collection is complete and water chemistry is verified, the design basis for the J-3 plume ETR system can be established, and the detailed design can commence.

Following is a list of data needs and investigative activities that are required prior to completion of final design of the J-3 plume ETR system:

- evaluation of results from Pew Road and other studies;
- evaluation of integration with existing facility communications system;
- evaluation of integration with facility piping, equipment, and power distribution; and
- evaluation of vehicle and maintenance access inside the FS-12 building.

7.0 SYSTEM PERFORMANCE MONITORING

A system performance monitoring plan will be developed to identify the sampling and monitoring necessary during baseline, start-up and routine monitoring phases of the system operations. This section presents the plan contents.

7.1 TREATMENT PLANT PERFORMANCE MONITORING

Treatment plant monitoring focuses on the operation of the treatment plant, the extraction wells, injection wells, well pumps and all associated piping. The system will include the appropriate levels of alarms and safety switches to allow for continual operation. The system will be installed with logic and analog controls to allow for off-site monitoring of select operational parameters.

A baseline monitoring event will be conducted prior to system start-up. The baseline event is intended to provide a comprehensive account of plume characteristics prior to the initiation of active remediation. This baseline event will also include sampling of the influent and effluent process water at the time of system start-up.

Routine operational monitoring will occur at agreed-upon locations after start-up, as well as operational monitoring of system influent and effluent characteristics. Sampling for COCs will be conducted at select locations within the treatment system components, including the extraction wells, combined influent (before treatment), effluent (after treatment) and between the initial and secondary treatment units, if applicable. During the start-up process, sampling will be conducted weekly for a month to verify mass removal and to assess initial trends in predicted influent contaminant mass characteristics. After the start-up process, the sampling will be conducted every two weeks for a month, and then monthly. These data will be evaluated to confirm treatment efficiency. Data evaluation techniques will employ calculations of mass removal rates and time series analysis. It is also expected that statistical analyses will be used to aid in the optimization of performance monitoring.

7.2 HYDRAULIC CONTROL MONITORING

Groundwater elevation will be monitored to assess the hydraulic effects of the extraction and recharge systems and their influence on the aquifer and plume characteristics. Groundwater elevations will be used to estimate horizontal and vertical gradients, to create groundwater flow maps and as input to recalibrate the groundwater model to verify capture of the plume. The draft plan will include the rationale, location and depths for monitoring wells to perform adequate hydraulic control monitoring.

Start-up hydraulic monitoring will consist of collecting water level measurements from a range of locations prior to the onset of pumping (related to J-3 Plume treatment) to obtain information that is unaffected by operational stress. During start-up, water levels will be measured frequently at select locations near the extraction and reinjection areas. The data will be used for a distance-drawdown evaluation to assess capture, and to provide updated information on aquifer hydraulic conductivity and transmissivity. These data, in turn, will be used for model validation and refinement, and capture demonstration.

After the initial hydraulic assessment is completed, hydraulic monitoring will be limited to quarterly water level monitoring at selected wells and surface water locations in a subregional (plume-specific) synoptic network. These data will be used periodically to verify flow model predictions and evaluate trends due to ambient hydraulic stresses (e.g., recharge, private and municipal extraction) and any revisions to pumping rates in the J-3/FS-12 treatment system.

7.3 PLUME NATURE AND EXTENT

Analytical sampling for explosives and perchlorate will continue for monitoring wells currently in the LTGM, as well as additional wells designated specifically for ETR performance monitoring. This will provide an opportunity to evaluate changes in the nature, extent, and concentration of contaminants in the plume. Monitoring outside the plume boundaries will be used to document that the plume has not moved beyond its original boundary during system operation, or migrated outside the expected plume trajectory. This will include lateral extent monitoring as well as downgradient plume monitoring so that reductions in plume mass, volume, and geographic extent can be monitored. Trend analyses will be performed to evaluate overall changes in plume mass and dynamics, as well as individual well data.

7.4 MONITORING WELL NETWORK

It is anticipated that wells selected for hydraulic and plume delineation purposes will be included in the monitoring well network. Background wells outside the area of system influence will be included to evaluate long-term aquifer changes affecting system performance. Monitoring wells will be included to assess whether contaminant concentrations are dropping immediately downgradient of the extraction wells. Plume delineation wells will include locations for monitoring of explosives and perchlorate concentrations as well as groundwater elevations to assess capture performance. Select wells in and immediately adjacent to the J-3 Plume will be included in the system performance monitoring plan.

7.5 ECOLOGICAL IMPACT MONITORING

Ecological impact monitoring will be performed to confirm that there has been minimal impact on the surrounding groundwater and surface water. It is expected that this will be a one-time effort that will be performed upon confirmation of a final wellfield design. Potential hydraulic impacts will be assessed using model simulations. Previous ecological impact monitoring results for FS-12 and other treatment systems at MMR have never indicated adverse impacts on adjacent ecological systems. Because the augmentation of the FS-12 treatment system to treat J-3 Plume contamination represents a relatively minor hydraulic change to the aquifer, only a one-time ecological assessment is deemed necessary.

In previous ecological assessments, chemical analyses of surface water, groundwater, and treatment plant effluent and physicochemical analyses of treatment plant influent and effluent were used to assess potential impacts on ecosystems downgradient of a treatment system. Several assessments (e.g., Section 4.3 of AFCEE 2002b) have shown that no adverse ecological impacts will occur as a result of chemical changes to groundwater prior to reinjection (or reinfiltration) to the aquifer, so no ecological impact assessments related to chemical data are proposed.

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8.0 SCHEDULE

This section discusses schedule considerations for the implementation of the J-3 Range RRA. Timeframes, key assumptions and constraints for the major phases of work are presented.

8.1 PLANNING AND PRE-DESIGN DATA COLLECTION

Planning for the J-3 plume RRA includes the activities that are required subsequent to the submittal of the draft RRA plan to achieve regulatory concurrence and community acceptance. The RRA plan is scheduled to be finalized by 27 July 2004. A presentation of the RRA plan to the Impact Area Review Team (IART) followed by a 15-day public comment period is assumed prior to finalization. Inter-active planning to develop schedule details may be beneficial during and/or after resolution of comments on the draft RRA plan.

Limited additional pre-design data collection are needed to conduct wellfield design modeling. These activities include a synoptic water level survey of vicinity monitoring wells and surveys of vertical and horizontal coordinates for a subset of wells that are currently lacking reliable coordinate data. These efforts are expected to require an overall duration of 2 to 3 weeks and may proceed independently; however, prior to the synoptic survey, AFCEE O&M will be contacted to verify the operational condition for the FS-12 system. The execution of field activities on private property will be prohibited based on landowner conditions between late May and early September. If the required field activities are not performed prior to the period of restriction, the overall project schedule will be significantly impacted.

8.2 PROPERTY ACCESS AND PERMITTING

It will be essential to obtain some level of agency concurrence on the proposed RRA and engage the owners of the Camp Good News (CGN) property early to determine their acceptance of the planned project and obtain permission to access the property for pre-design fieldwork. Access to CGN has generally been prohibited during the summer in regard to environmental restoration efforts under the AFCEE program and it is expected that these restrictions will apply to field activities related to the J-3 plume RRA. It is anticipated that, based on the landowner cooperation experienced during the construction and operation for the FS-12 remedial system, the related existing government easement, and the likelihood that project development can be limited to the extent of the current easement, a formalized property access process will not be a critical driver for the project schedule.

The permitting process for the project will need to address cultural and natural resource clearance requirements. These efforts are expected to proceed under the direction of Camp Edwards Environmental and Readiness Center staff. Site visits to CGN associated with this effort should be conducted prior to the landowner-imposed period of access restriction (late - May through mid - September). Approximately 2 months are estimated to be required to obtain required cultural and natural resource clearances.

8.3 WELLFIELD DESIGN AND SYSTEM ENGINEERING

The wellfield design will be completed after model calibration using the synoptic groundwater evaluation data. This effort is expected to require 2 months to complete, once the synoptic water level and survey control data are available, and it is assumed that this work will be performed in parallel with RRA document finalization. It is anticipated that regulatory concurrence on the RRA wellfield design can be achieved via a streamlined review and approval process specifically focused on this critical component of the project. Documentation of the wellfield design approval effort is proposed to be via project note. Concurrence on the wellfield design will trigger the development of a detailed engineering design of the treatment system. Modeling and system engineering progress reports will be provided to regulatory stakeholders at key points in the design process. Assuming that property access restrictions are avoided for key predecessor activities and that design concurrence and documentation proceeds using a streamlined method, it is possible for a final design to be issued in early 2005.

8.4 PROCUREMENT AND CONSTRUCTION

The purchase of equipment and materials and contracting required to construct the J-3 plume RRA system will be initiated as key phases of the engineering design effort are completed. For example, after concurrence of the 60 percent design, anticipated to be in late 2004 (if predecessor assumptions hold), the procurement of long lead process equipment can be initiated. Keeping with this logic, the purchase of pipeline material, well vaults, and the award of the extraction well refurbishment subcontract can also proceed at this phase. Material fabrication and delivery requirements are estimated to require 4 months. The award of the plant mechanical subcontract and electrical, instrumentation, and communications subcontract will depend on plans and specifications that will be available at the 90 percent stage. The total duration for contracting and procurement is anticipated to take 3.5 months.

The construction schedule will be expedited due to the existence of the three surplus FS-12 extraction wells and treatment plant structure. Initial activities will focus on redevelopment of the existing wells and placement of the vaults, followed by pipeline placement. Again, it must be stressed that based on knowledge of landowner requirements established during the construction and operation of AFCEE's FS-12 remedial system, activities on CGN property will likely be prohibited from late May though early September. The overall duration of construction effort preceding system start-up is estimated to be 4.5 months. Construction is preceded by system design and contracting and procurement.

8.5 PERFORMANCE MONITORING

Pending finalization of the RRA plan and concurrence on the wellfield design, a system performance monitoring plan will be prepared and submitted for agency concurrence. This plan will address design verification and optimization through the collection of appropriate chemical and physical data under baseline (pre-operational) conditions and during system operation. Seasonal access restrictions for CGN locations are expected to limit field monitoring at these locations to the period from mid September to late May.

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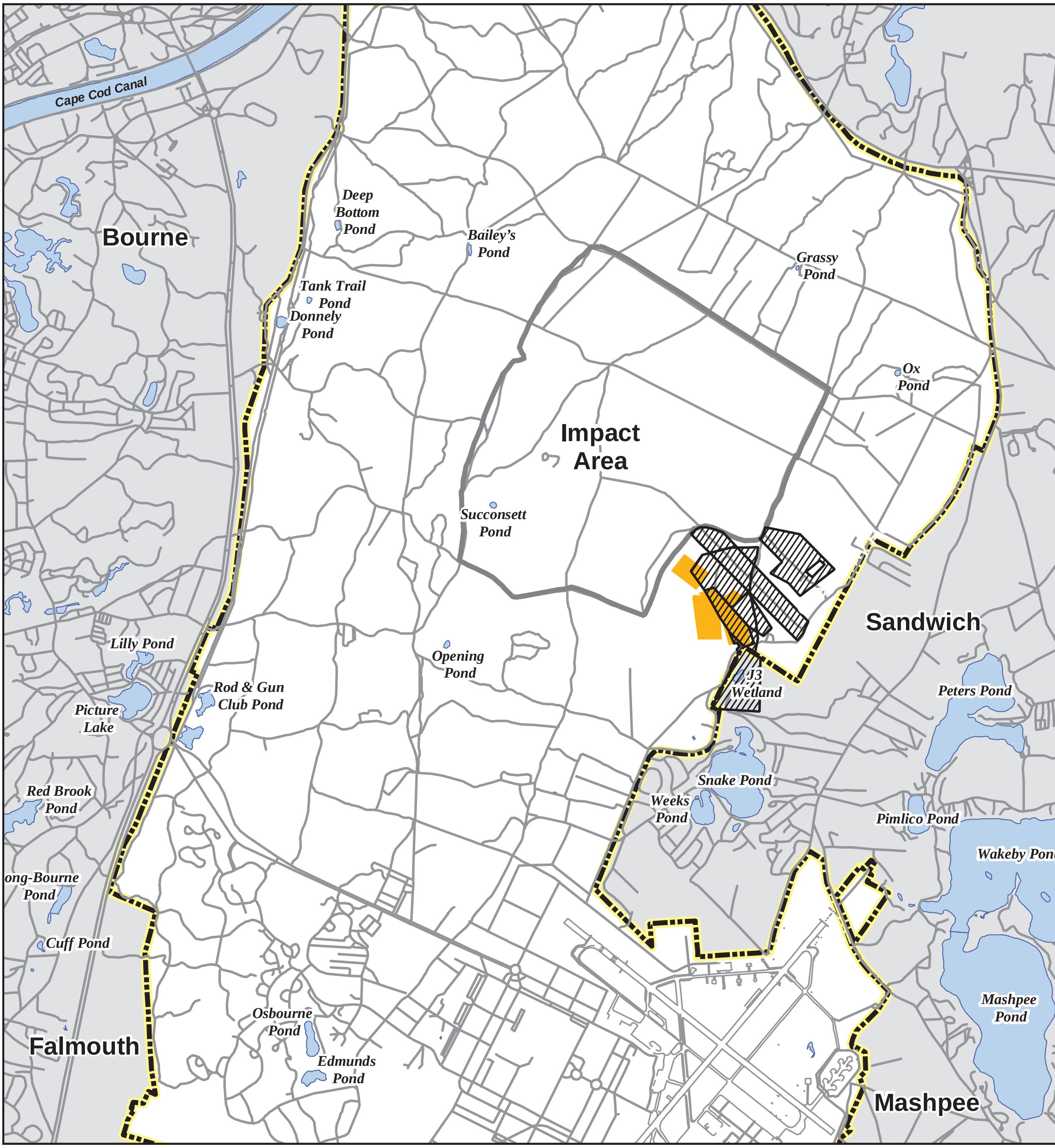

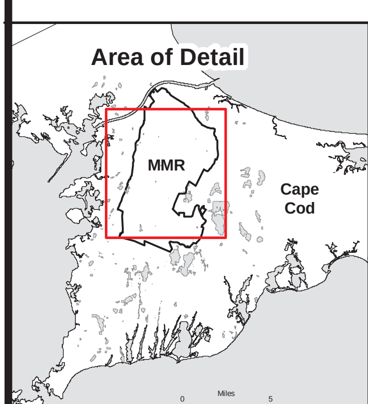

Legend

- Southeast Ranges Area
- J-3 Range Study Areas
- MMR Boundary

N
W
E
S

0 6,000 Feet

Impact Area Groundwater Study Program

Location of J-3 Range Study Areas

Massachusetts Military Reservation
Cape Cod, Massachusetts

NAME: jpiccuito DATE: 3/23/2004

Figure 1-1

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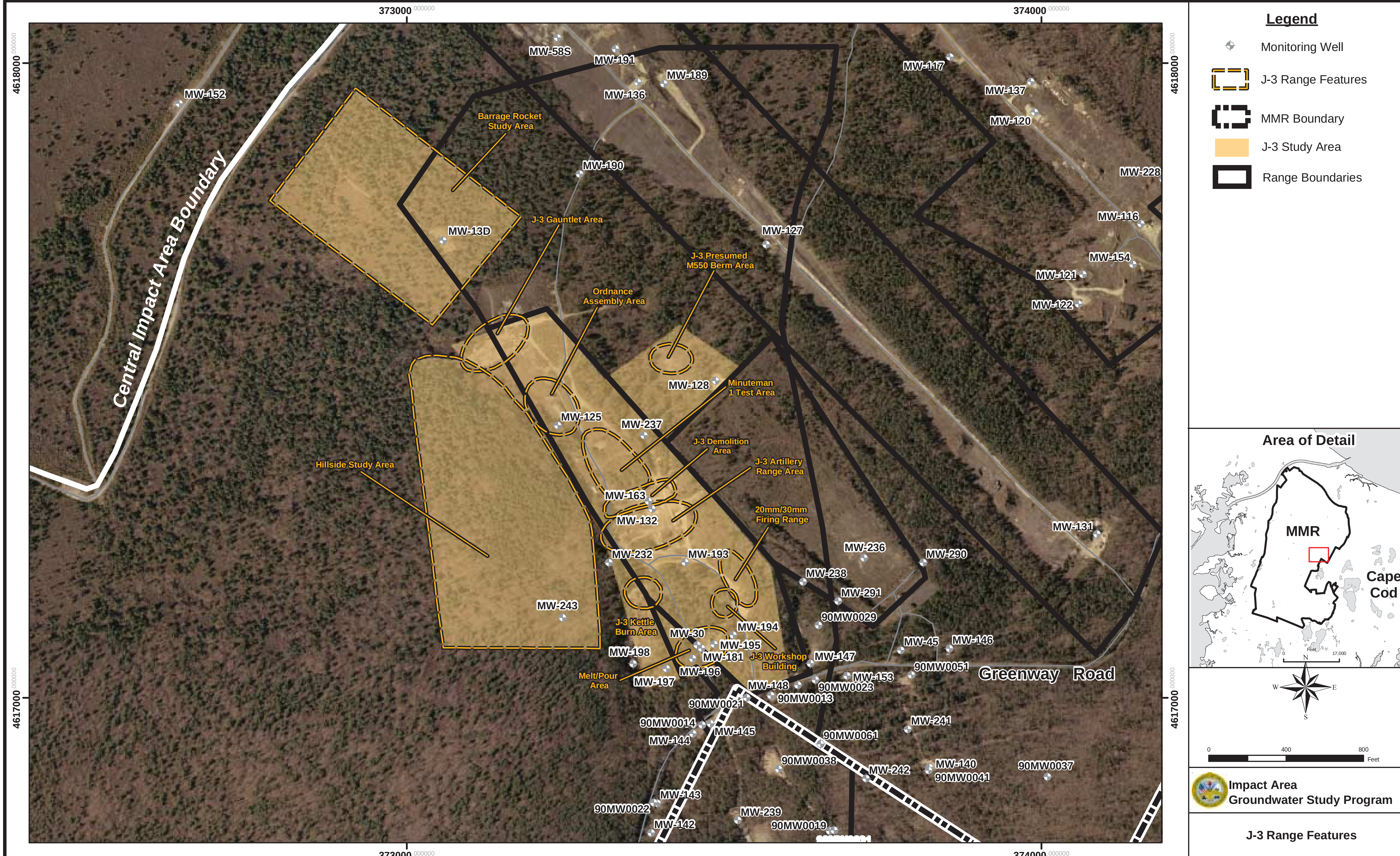


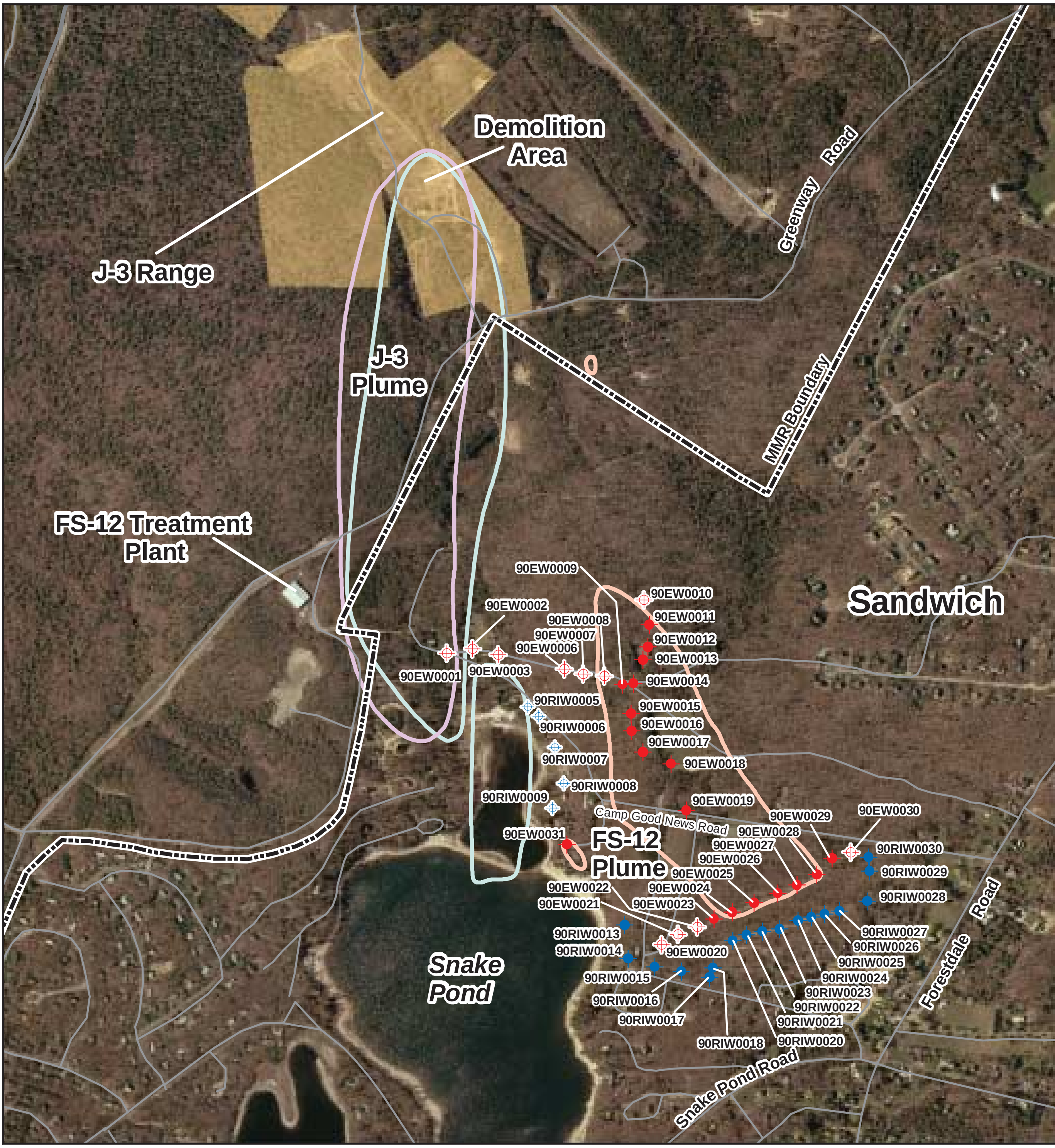
Aerial Photography ARNG 2002

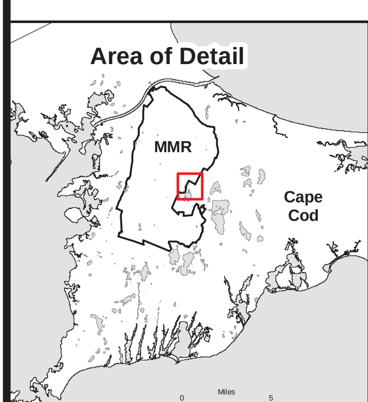
Massachusetts Military Reservation
Cape Cod, Massachusetts

NAME: jpiccuito DATE: 3/23/2004

Figure 1-2

Y:\IA_TERC\Projects\352AY53\30\20040323\ArcGIS\j3_source_areas_rra2.mxd





Legend

EDB and Benzene Contour = Represents an exceedance of ethylene dibromide (1,2-dibromoethane; EDB MMCL = 0.02 µg/L) and an exceedance of benzene (MCL = 5.0 µg/L; AFCEE 2004)

Perchlorate contour, represents concentrations greater than 0.35 µg/L for perchlorate (approximate detection limits) (AMEC EDMS Website June 2003)

RDX contour, represents concentrations greater than 0.06 µg/L for RDX (approximate detection limits) (AMEC EDMS Website June 2003)

Extraction well (Non operational)

Extraction well operational

Reinjection well (Non operational)

Reinjection well operational

J-3 Range Study Areas

MMR Boundary

Source: FS-12 plume (AFCEE 2004)

N
W
E
S

0 1,000 Feet

Impact Area Groundwater Study Program

Location of J-3 and FS-12 Plumes

Massachusetts Military Reservation
Cape Cod, Massachusetts

NAME: jpiccuito DATE: 3/23/2004

Figure 1-3

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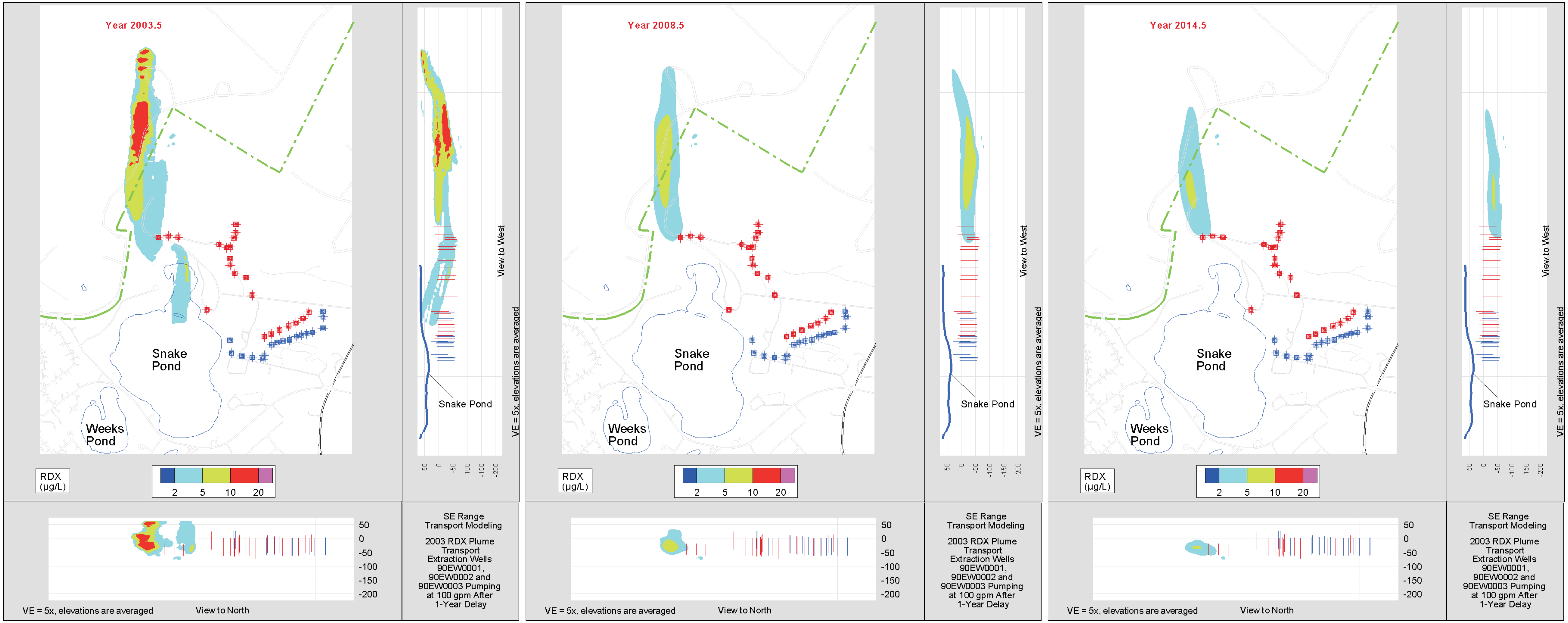


Legend

- Extraction Well
- Reinjection Well

Notes

RDX Health Advisory = 2 µg/L

Decay Half-life = 0

Horizontal Dispersivity = 15.0 ft.

Transverse Dispersivity = 0.15 ft.

Vertical Dispersivity = 0.015 ft.

FS-12 = Fuel Spill-12

ft = feet

RDX = hexahydro-1,3,5-trinitro-1,3,5-triazine

VE = vertical exaggeration

µg/L = micrograms per liter

N

0 1800

Scale in Feet

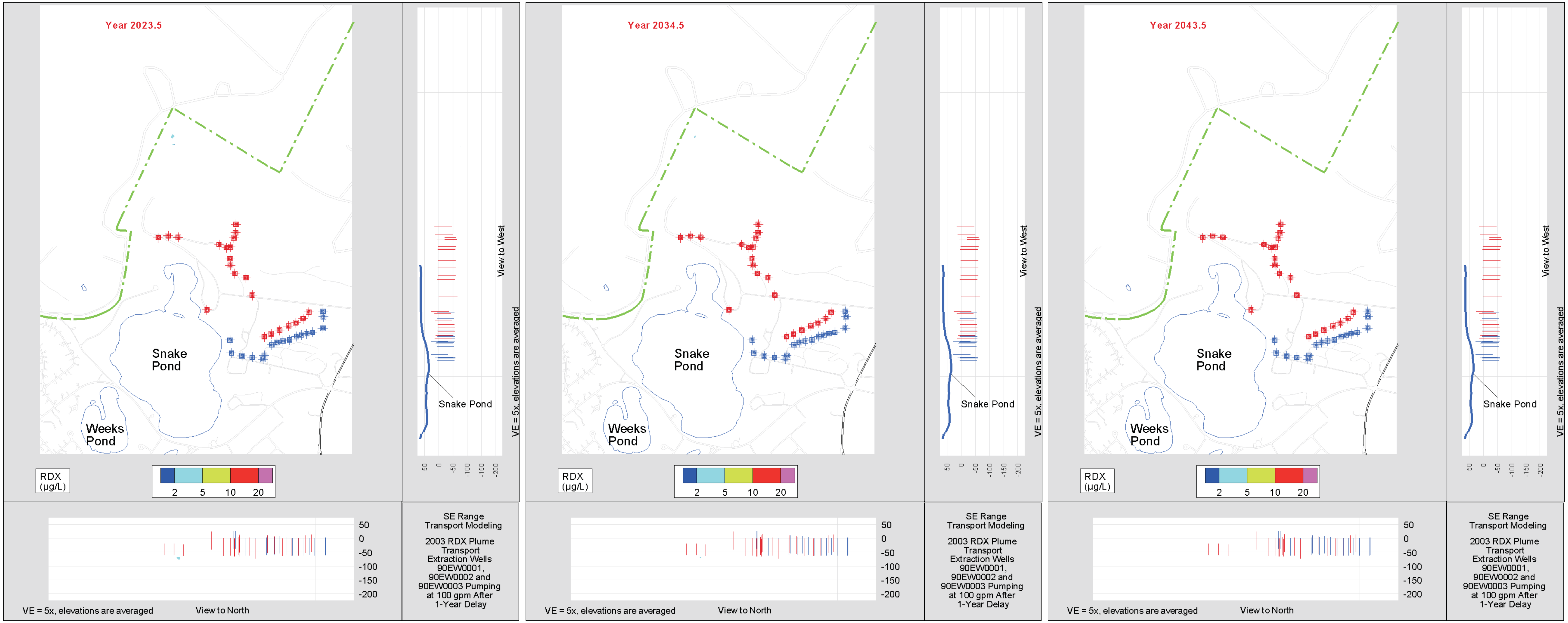
Impact Area Groundwater Study Program

J-3 Range Model-Predicted RDX Concentrations with Extraction Wells 90EW0001, 90EW0002 and 90EW0003 Operating at a Combined Flow Rate of 100 gpm

Massachusetts Military Reservation
Cape Cod, Massachusetts

3/29/04 DMF
Fig5-1a RDX_100gpm.cdr

Figure 5-1a



Legend

- Extraction Well
- Reinjection Well

Notes

RDX Health Advisory = 2 µg/L
Decay Half-life = 0
Horizontal Dispersivity = 15.0 ft.
Transverse Dispersivity = 0.15 ft.
Vertical Dispersivity = 0.015 ft.

FS-12 = Fuel Spill-12
ft = feet
RDX = hexahydro-1,3,5-trinitro-1,3,5-triazine
VE = vertical exaggeration
µg/L = micrograms per liter

N
0 1800
Scale in Feet

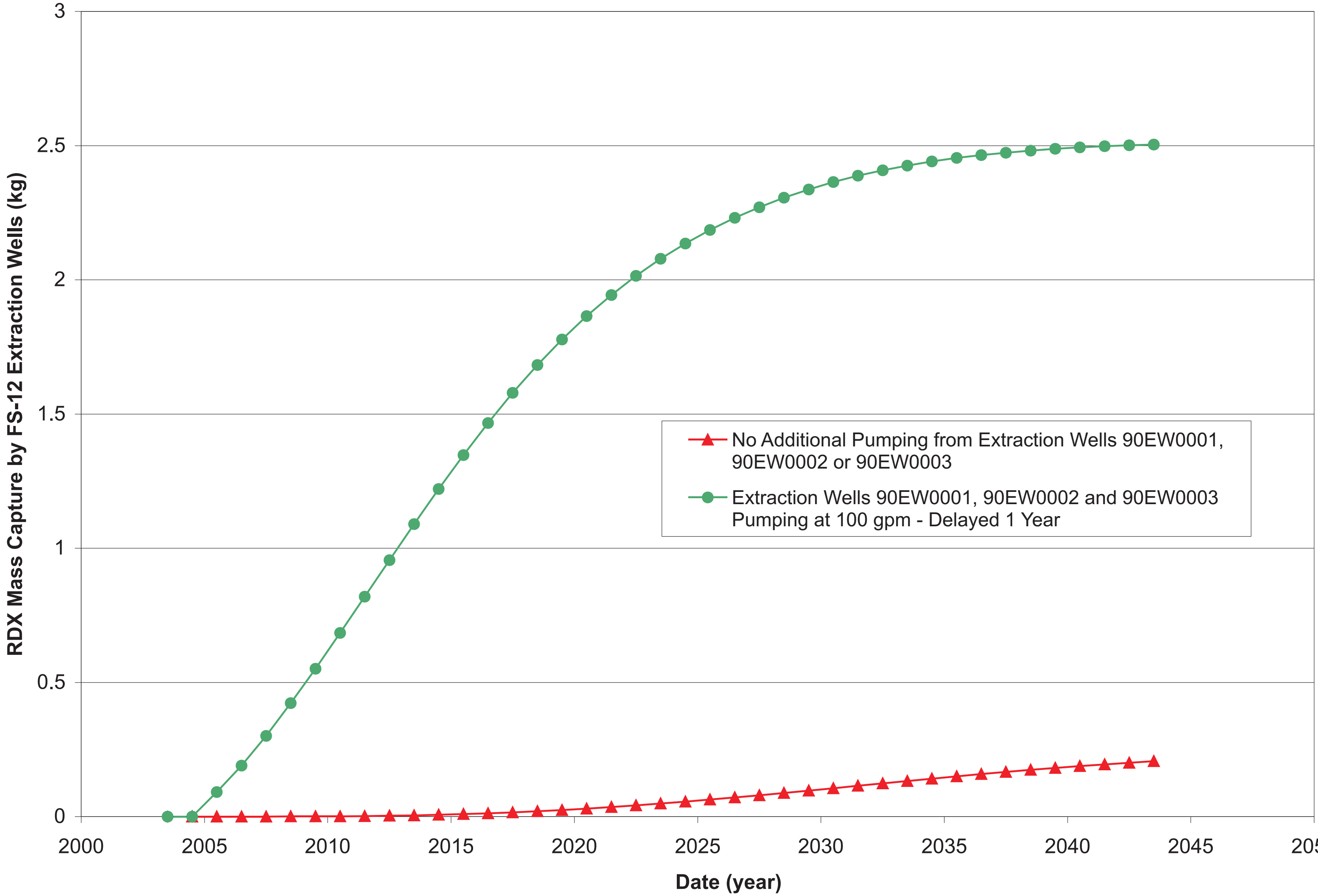
Impact Area Groundwater Study Program

J-3 Range Model-Predicted RDX Concentrations with Extraction Wells 90EW0001, 90EW0002 and 90EW0003 Operating at a CombinedFlow Rate of 100 gpm

Massachusetts Military Reservation
Cape Cod, Massachusetts

3/29/04 DMF
Fig5-1b RDX_100gpm.cdr

Figure 5-1b



Notes

FS-12 = Fuel Spill-12

gpm= gallons per minute

kg = kilograms

RDX = hexahydro-1,3,5-trinitro-1,3,5-triazine

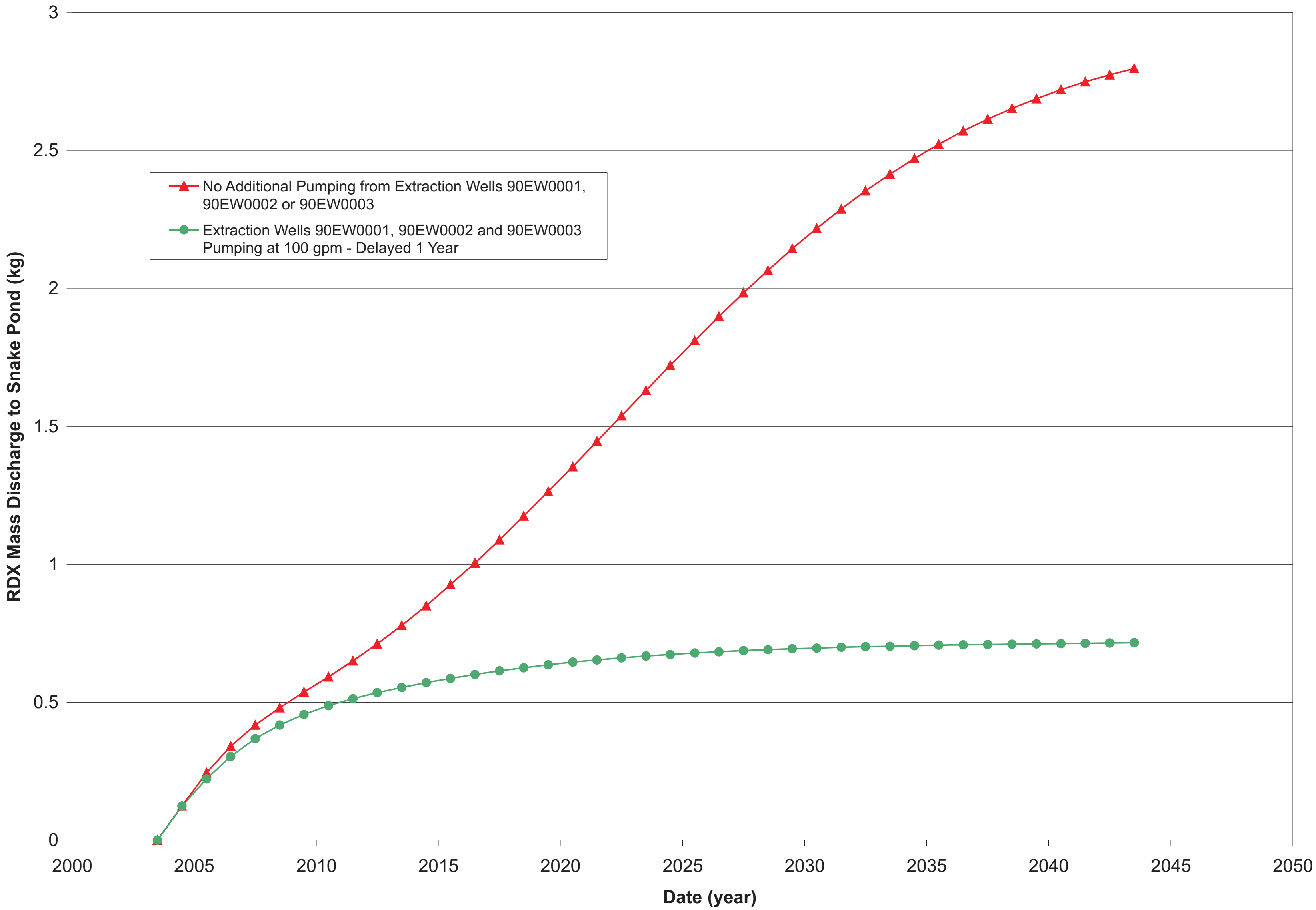
Impact Area Groundwater Study Program

Model-Predicted RDX Mass Capture with and without Extraction Wells 90EW0001, 90EW0002 and 90EW0003 Operating

Massachusetts Military Reservation
Cape Cod, Massachusetts

4/7/04 DF
Fig5-2_Mass_Capt_Delayed.cdr

Figure 5-2



Notes

gpm= gallons per minute

kg = kilograms

RDX = hexahydro-1,3,5-trinitro-1,3,5-triazine

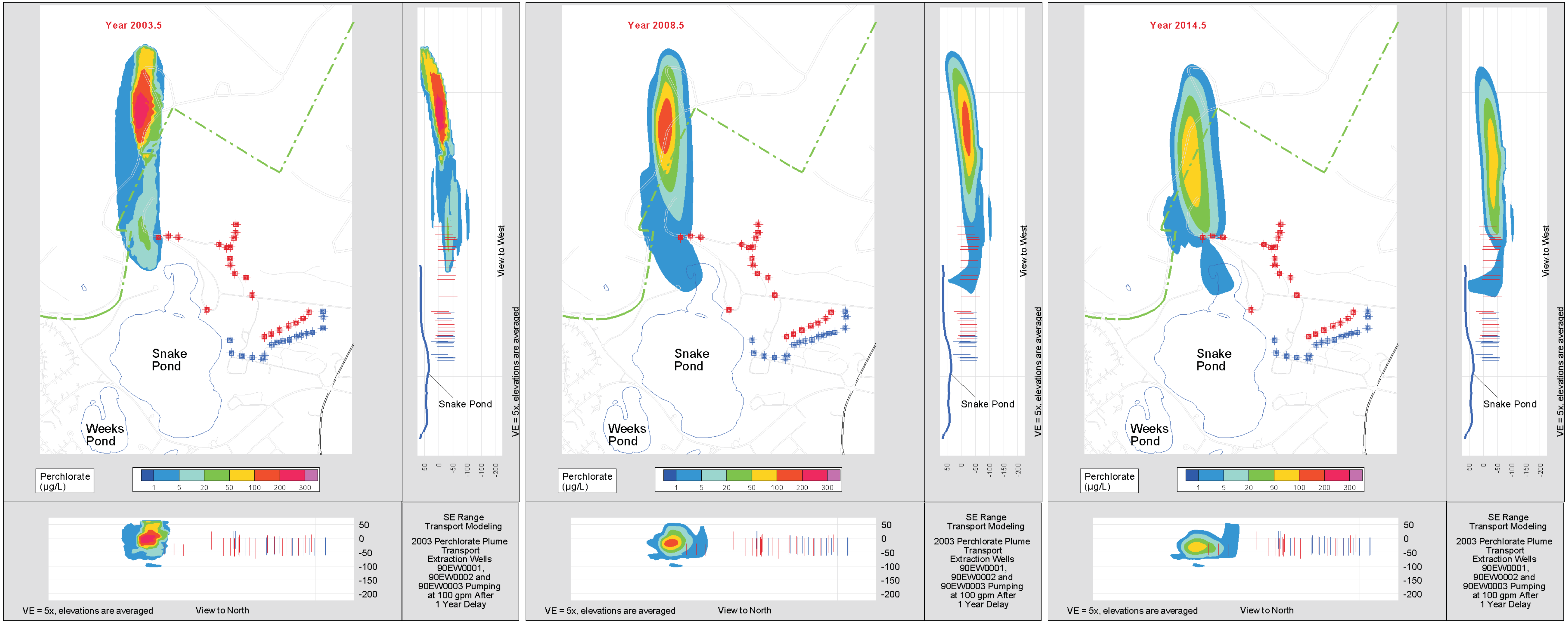
Impact Area Groundwater Study Program

Model-Predicted RDX Mass Discharge to Snake Pond with and without Extraction Wells 90EW0001, 90EW0002 and 90EW0003 Operating

Massachusetts Military Reservation
Cape Cod, Massachusetts

4/7/04 DF
Fig5-3_Mass Disch_Delayed.cdr

Figure 5-3



Legend

- Extraction Well
- Reinjection Well

Notes

State of MA guidance level = 1 µg/L
Decay Half-life = 0
Horizontal Dispersivity = 15.0 ft.
Transverse Dispersivity = 0.15 ft.
Vertical Dispersivity = 0.015 ft.

FS-12 = Fuel Spill-12
ft = feet
RDX = hexahydro-1,3,5-trinitro-1,3,5-triazine
VE = vertical exaggeration
µg/L = micrograms per liter

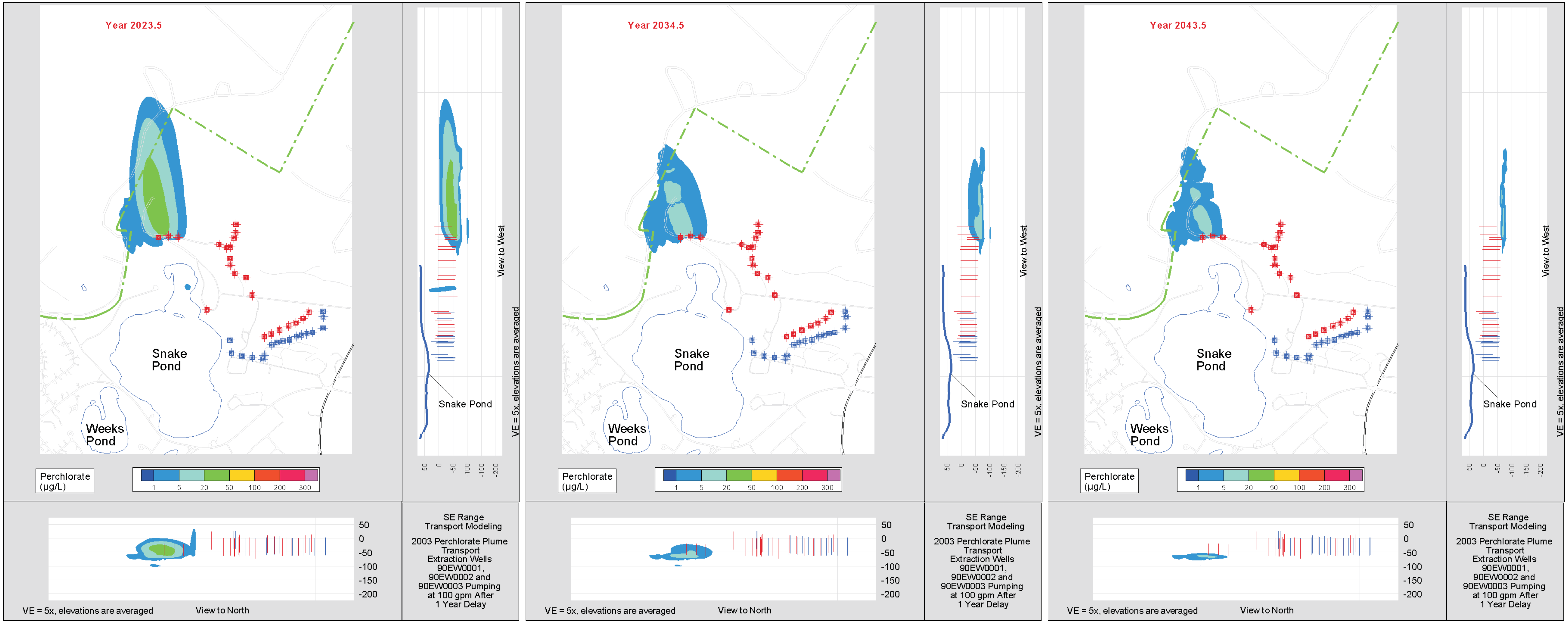
N
0 1800
Scale in Feet

Impact Area Groundwater Study Program

Model-Predicted Perchlorate Concentrations with Extraction Wells 90EW0001, 90EW0002 and 90EW0003 Operating at a Combined Flow Rate of 100 gpm
Massachusetts Military Reservation
Cape Cod, Massachusetts

4/7/04 DMF
Fig5-4a Perc_100gpm.cdr

Figure 5-4a



Legend

- Extraction Well
- Reinjection Well

Notes

State of MA guidance level = 1 µg/L

Decay Half-life = 0

Horizontal Dispersivity = 15.0 ft.

Transverse Dispersivity = 0.15 ft.

Vertical Dispersivity = 0.015 ft.

FS-12 = Fuel Spill-12

ft = feet

RDX = hexahydro-1,3,5-trinitro-1,3,5-triazine

VE = vertical exaggeration

µg/L = micrograms per liter

N

0 1800

Scale in Feet

Impact Area Groundwater Study Program

Model-Predicted Perchlorate Concentrations with Extraction Wells 90EW0001, 90EW0002 and 90EW0003 Operating at a Combined Flow Rate of 100 gpm

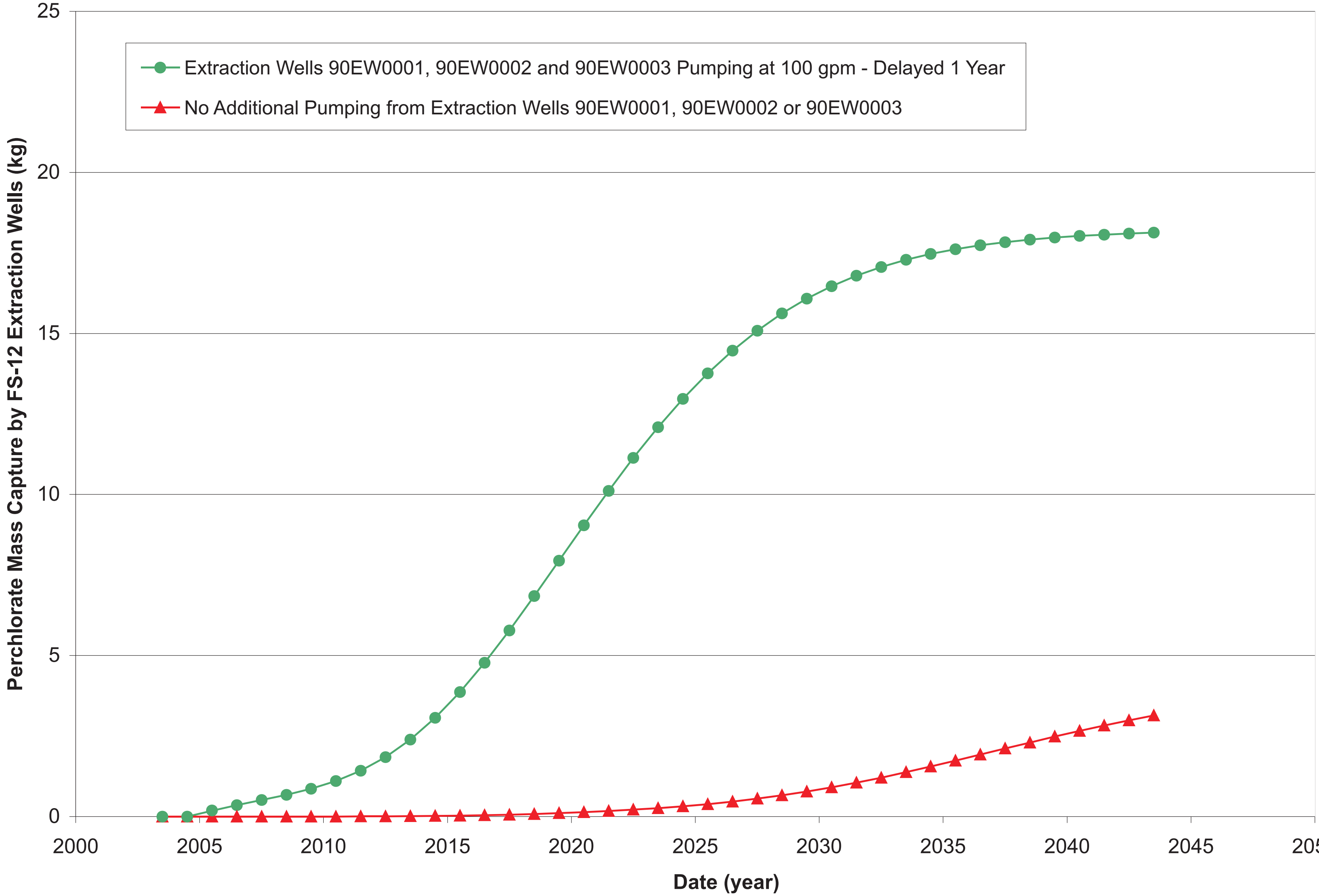
Massachusetts Military Reservation

Cape Cod, Massachusetts

4/7/04 DMF

Fig5-4b Perc_100gpm.cdr

Figure 5-4b



Notes

FS-12 = Fuel Spill-12

gpm = gallons per minute

kg = kilograms

Impact Area Groundwater Study Program

Model-Predicted Perchlorate Mass Capture with and without Extraction Wells 90EW0001, 90EW0002 and 90EW0003 Operating

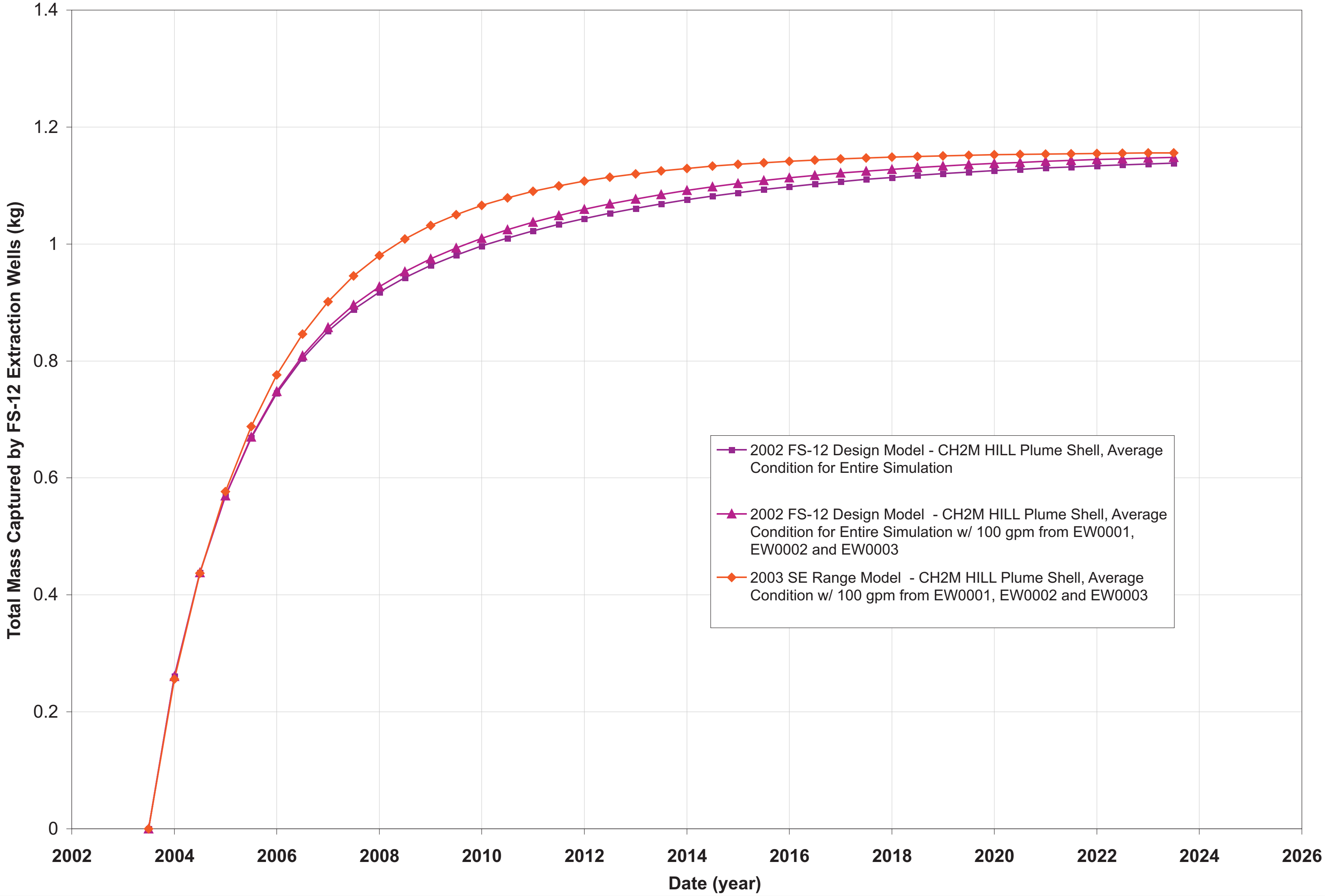
Massachusetts Military Reservation

Cape Cod, Massachusetts

4/7/04 DF

Fig5-5_Mass_Capture_Percl.cdr

Figure 5-5



Notes

FS-12 = Fuel Spill-12

gpm = gallons per minute

kg = kilograms

Impact Area Groundwater Study Program

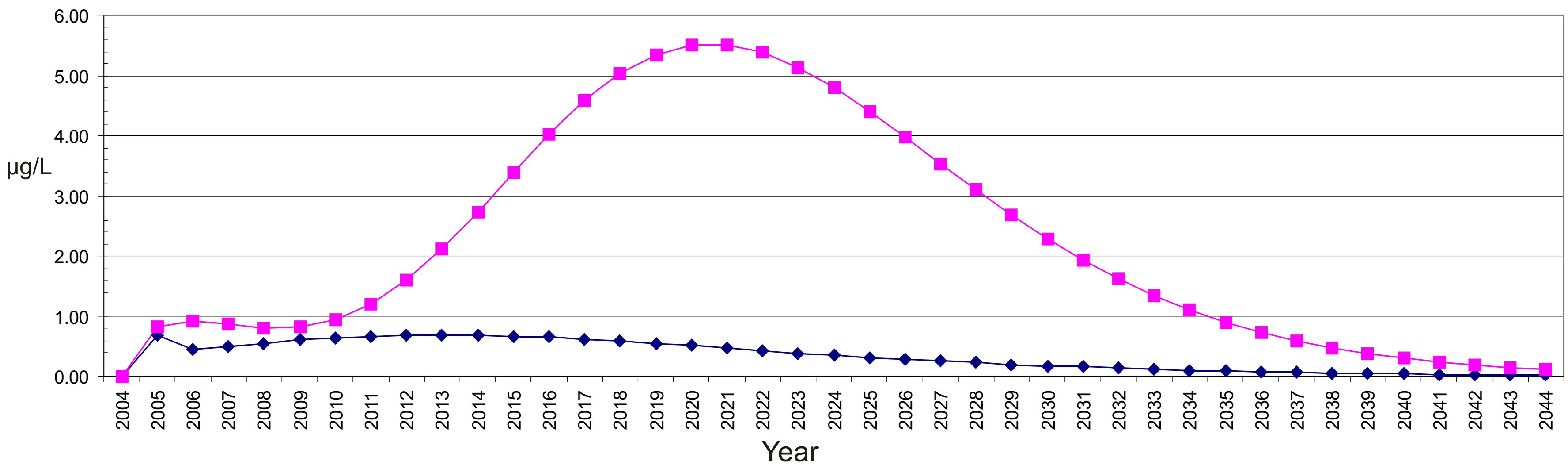
Model-Predicted FS-12 Mass Capture in the FS-12 Design and SE Range Models

Massachusetts Military Reservation

Cape Cod, Massachusetts

3/18/04 DF
Fig5-6_2003 CH2M Shell FS12 Mod.cdr

Figure 5-6



Legend

RDX Influent — Perchlorate Influent

gpm = gallons per minute
µg/L = micrograms per liter
RDX = hexahydro-1,3,5-trinitro-1,3,5-triazine

Pumping Rates (gpm)

90EW0001	= 50
90EW0002	= 25
90EW0003	= 25

Impact Area Groundwater Study Program

Long-Term Average Annual Combined Influent Concentrations for Extraction Wells 90EW0001, 90EW0002, and 90EW0003

Massachusetts Military Reservation
Cape Cod, Massachusetts

3/30/04 NZ : figure5_7.cdr

Figure 5-7

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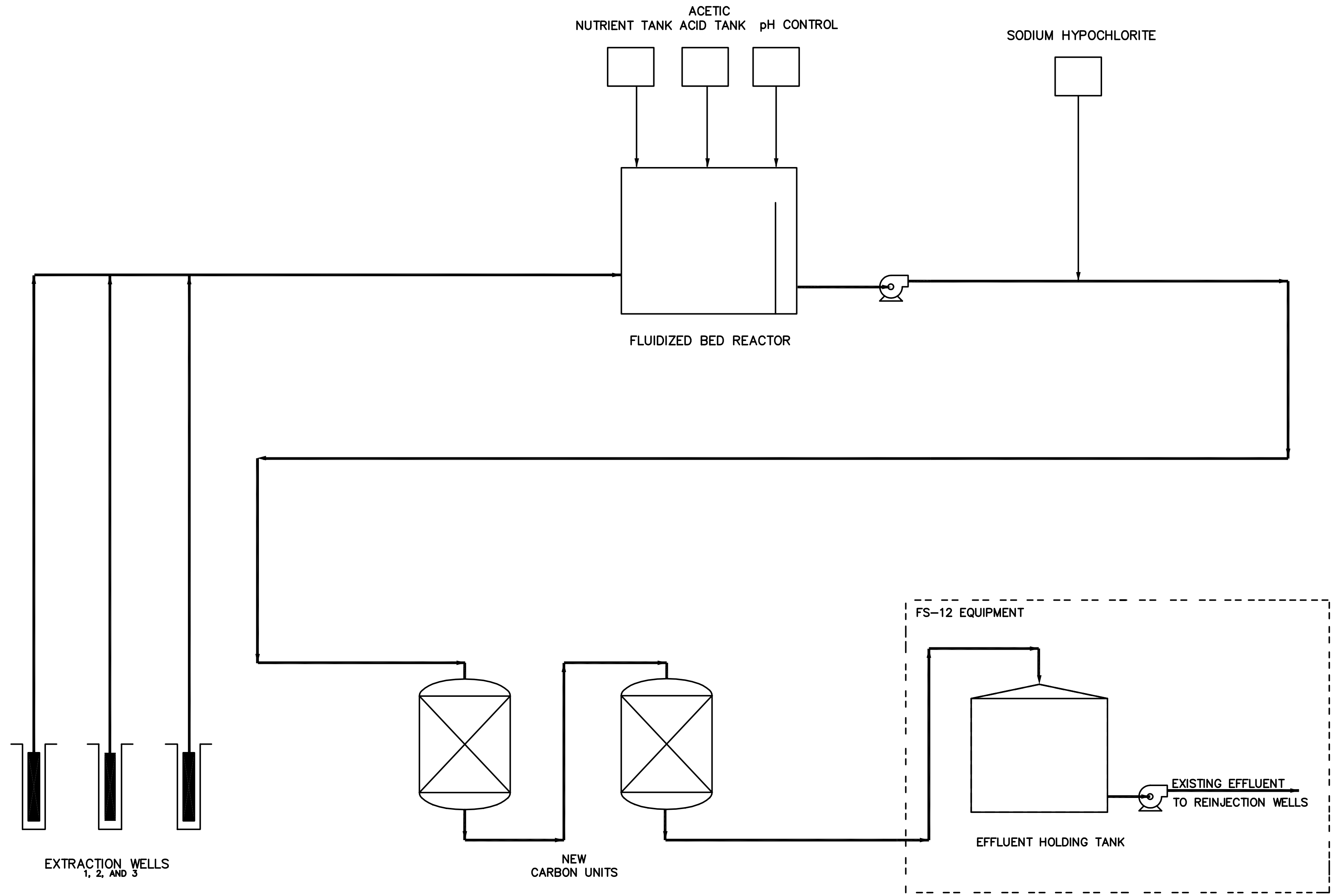

Impact Area
Groundwater Study Program

J-3 Plume RRA
Proposed Treatment
FBR Flow Diagram

Massachusetts Military Reservation
Cape Cod, Massachusetts

04/27/04 KE BFD_PFD FBR_5_8.dwg

Figure 5-8

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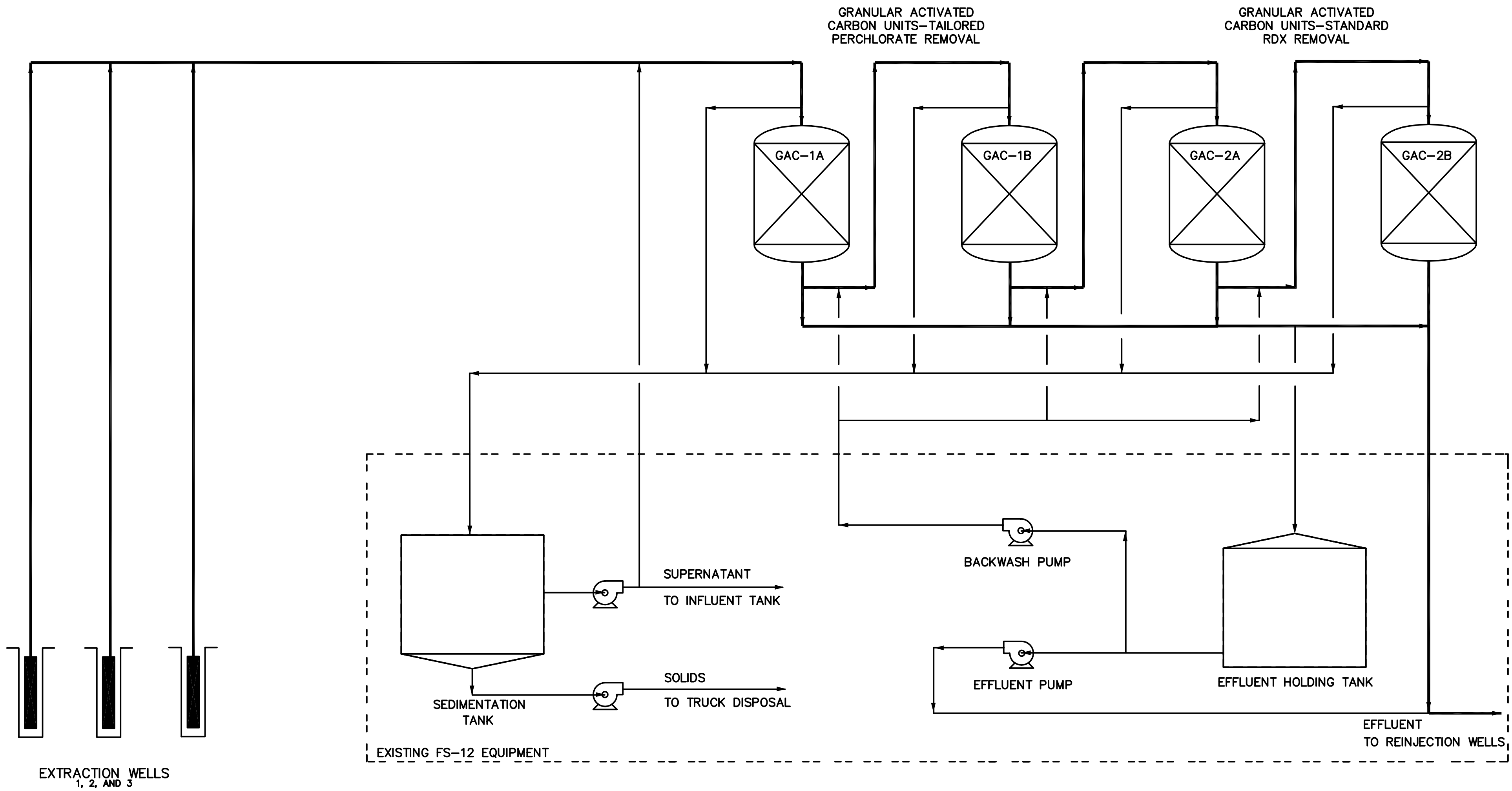

Impact Area
Groundwater Study Program

J-3 Plume RRA
Proposed Treatment
GAC Flow Diagram

Massachusetts Military Reservation
Cape Cod, Massachusetts

04/27/04 KE R1BFD_PFD GAC_5_9.dwg

Figure 5-9

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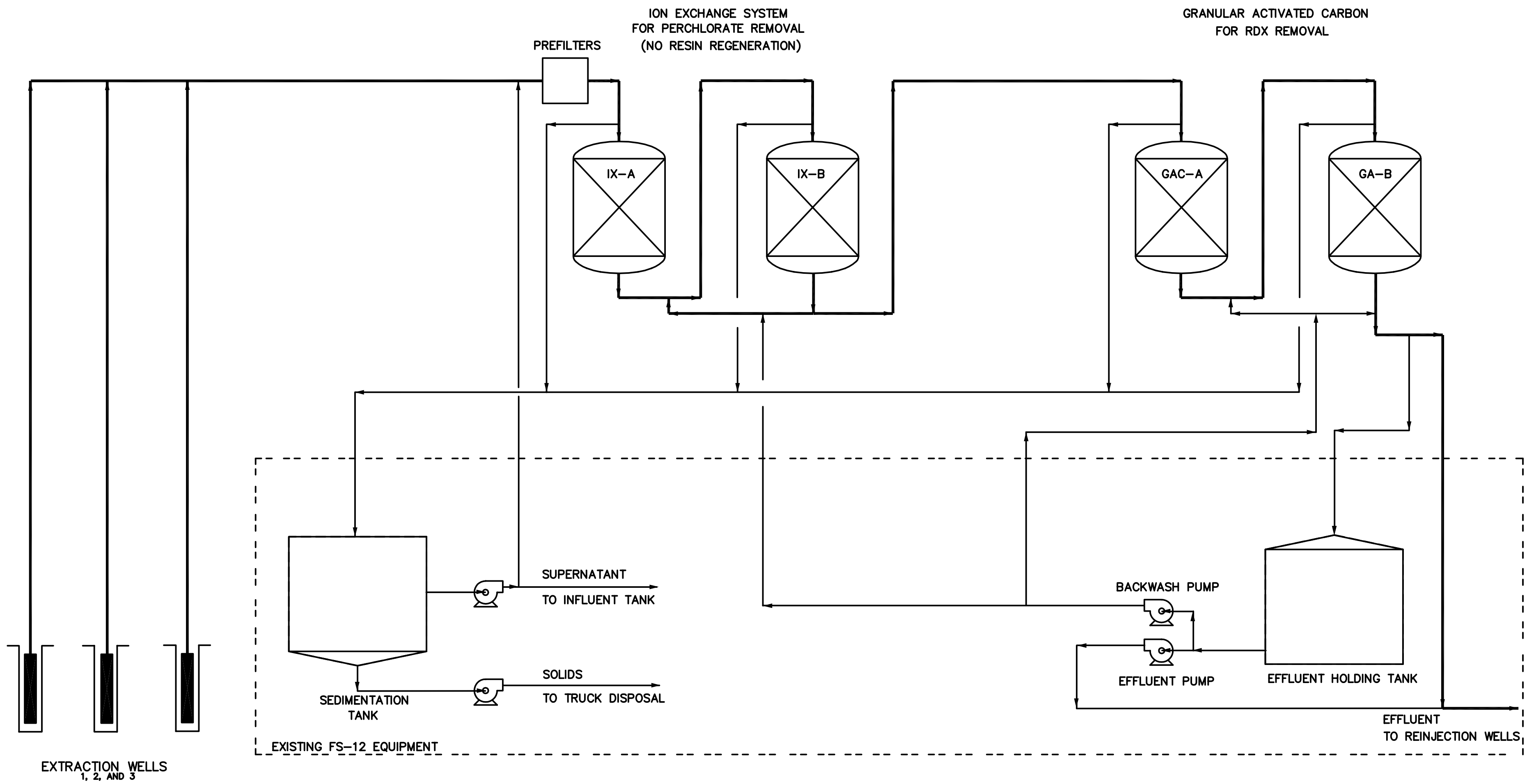

Impact Area
Groundwater Study Program

J-3 Plume RRA
Proposed Treatment
Ion Exchange Flow Diagram

Massachusetts Military Reservation
Cape Cod, Massachusetts

04/27/04 KE R1BFD_PFD ION X_5_10.dwg

Figure 5-10

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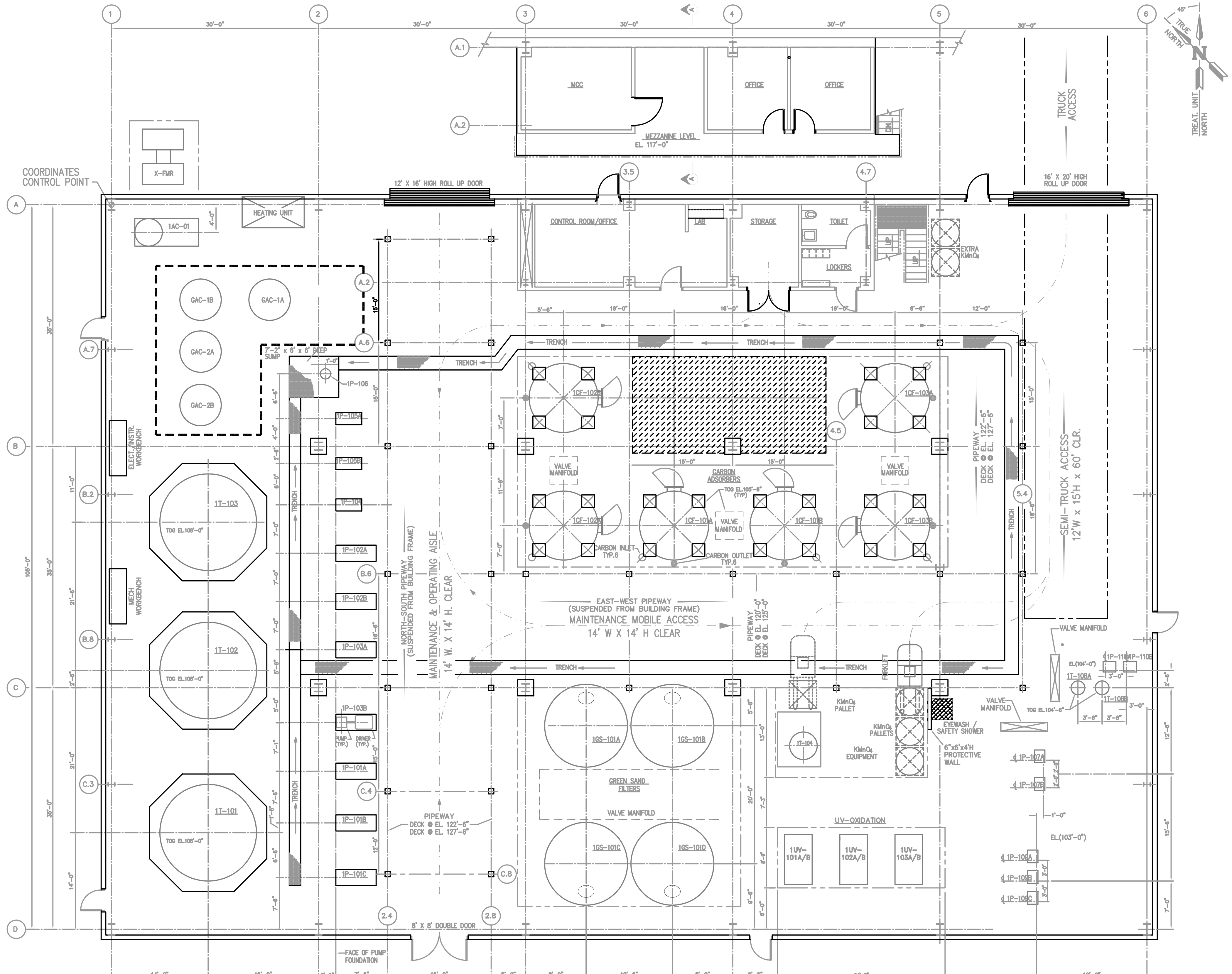

footprint for recommended GAC system

Source: FS-12 Facility General Arrangement, 1999

Impact Area
Groundwater Study Program

FS-12 Treatment Plant Layout with Proposed Footprint for J-3 GAC System

Massachusetts Military Reservation
Cape Cod, Massachusetts

04/27/04 KE GA Sketch_5_11.dwg

Figure 5-11

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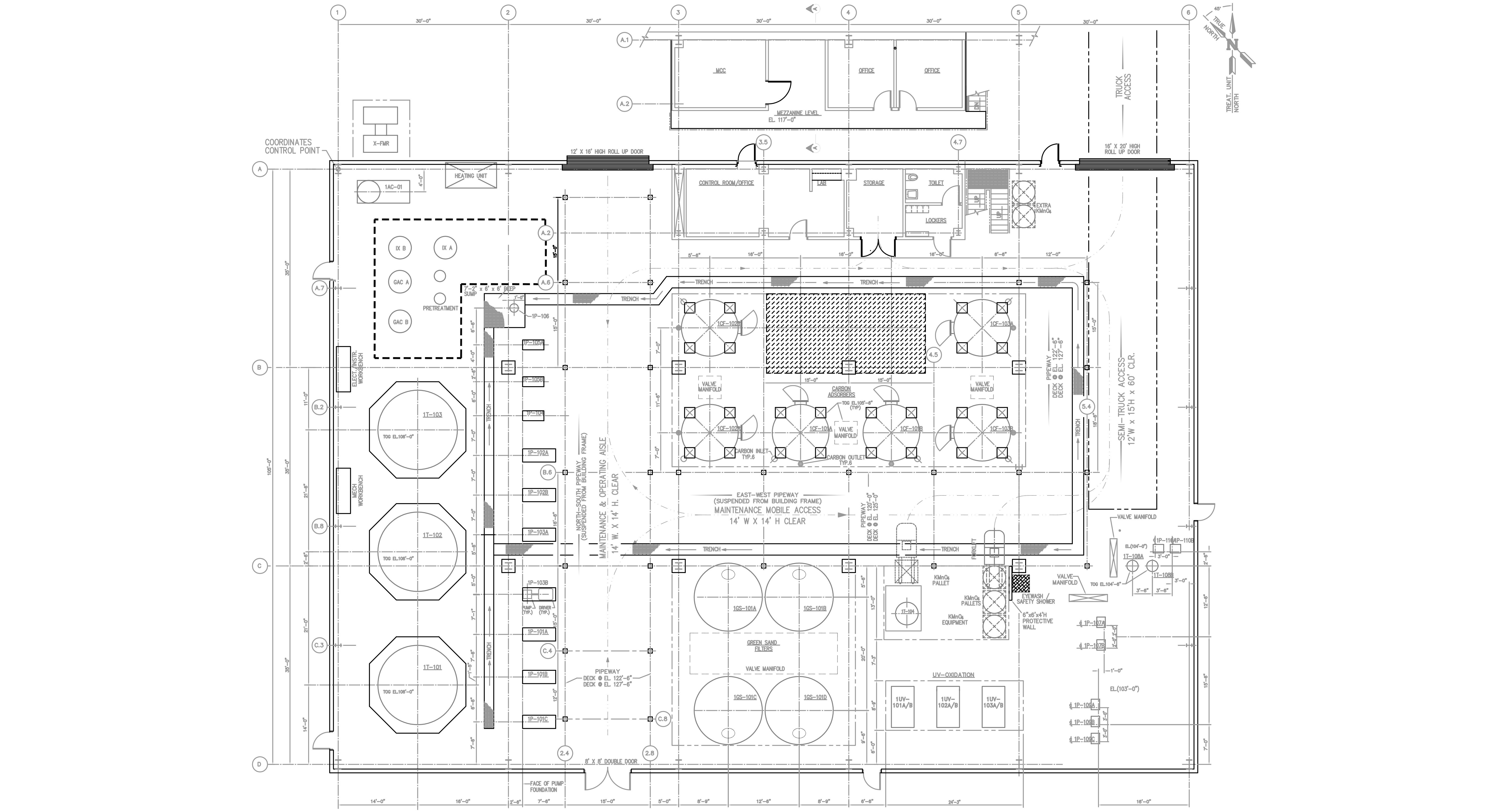

footprint for recommended Ion Exchange system

Source: FS-12 Facility General Arrangement, 1999

Impact Area Groundwater Study Program

FS-12 Treatment Plant Layout with Proposed Footprint for J-3 Ion Exchange System

Massachusetts Military Reservation
Cape Cod, Massachusetts

04/27/04 KE ION Sketch_5_12.dwg

Figure 5-12

Table 3-1
Summary of J-3 Plume Constituent Screening

Analyte	Number of Samples	Number of Detects	Units	Minimum Detect	Average Result[1]	Maximum Detect	Region 9 Tap Water PRG	Number of Results > PRG
Hexahydro-1,3,5-Trinitro-1,3,5-Triazine (RDX)	949	228	µg/L	0.25	2.16	20	6.1E-01	145
Octahydro-1,3,5,7-Tetranitro-1,3,5,7- Tetrazocine (HMX)	950	167	µg/L	0.26	5.26	88	1.8E+03	0
Perchlorate	554	177	µg/L	0.35	17.33	311	3.6E+00	62

Notes:
1. Average calculated using 0.5 times the DL for results reported as ND.

DL = detection limit
ND = nondetect
PRG = Preliminary Remediation Goals
µg/L = micrograms per liter

Table 4-1
Summary of Regulatory Considerations
J-3 Range Groundwater Plume RRA Plan

AUTHORITY/ TYPE	PROVISION	SYNOPSIS	ACTION TO BE TAKEN IN CONSIDERATION
Federal/ Chemical Specific	SDWA MCLs, 40 CFR 141.61 – 141.63	The EPA has promulgated SDWA. MCLs (40 CFR 141-143) that are enforceable standards for public drinking water supplies. The standards protect drinking water quality by limiting the levels of specific contaminants that can adversely affect public health and are known or anticipated to occur in public water systems. EPA has granted Massachusetts primary enforcement authority for the SDWA primary drinking water regulations.	Cleanup goals established for both the FS-12 and J-3 actions considered federal MCLs.
State/ Chemical Specific	MA Drinking Water Regulations, 310 CMR 22.00	These standards establish Massachusetts MCLs (MMCLs) for public drinking water systems. When state regulations are more stringent than federal laws, the state MCLs should be used.	Cleanup goals established for both the FS-12 and J-3 actions considered Massachusetts MCLs (MMCLs) (310 CMR 22.00 et. seq.).
Federal/Action Specific	SDWA Sole Source Aquifer Program, Section 1424(e) of the SDWA, 47 FR 30282	Pursuant to Section 1424(e) of the Safe Drinking Water Act, the EPA has determined that the Cape Cod aquifer is the sole or principal source of drinking water for Cape Cod, Massachusetts, and that the Cape Cod aquifer, if contaminated, would create a significant hazard to public health. As a result of this determination, no commitment for Federal financial assistance may be entered into for any project that the Administrator determines may contaminate such aquifer through a recharge zone so as to create a significant hazard to public health. (47 FR 30282, Tuesday July 13, 1982)	Groundwater would be treated in accordance with Drinking Water Standards and Health Advisories before recharge so that this action will not contaminate the aquifer through a recharge zone.

Table 4-1
Summary of Regulatory Considerations
J-3 Range Groundwater Plume RRA Plan

AUTHORITY/ TYPE	PROVISION	SYNOPSIS	ACTION TO BE TAKEN IN CONSIDERATION
Federal/Action Specific	SDWA Underground Injection Control Program, 40 CFR 114, 146, 147, 1000	Underground Injection Control Program (40 CFR 114, 146, 147, 1000) regulations outline minimum program and performance standards for underground injection wells and prohibit any injection that may cause a violation of any primary drinking water regulation in the aquifer. These regulations are administered by the State. See description of State regulations below.	Extracted groundwater will be treated to levels at or below federal and state primary drinking water standards (i.e., MCLs) to ensure that discharges through reinjection to the receiving aquifer will not cause any violation of these standards in the aquifer.
State/Action Specific	MA Underground Injection Control Program, 310 CMR 27.00 et seq.	These regulations prohibit the injection of fluid containing any pollutant into underground sources of drinking water where such pollutant will or is likely to cause a violation of any state drinking water standard, or adversely affect the health of persons.	Extracted groundwater will be treated to levels at or below federal and state primary drinking water standards (i.e., MCLs) to ensure that discharges through reinjection to the receiving aquifer will not cause any violation of these standards in the aquifer.
State/Action Specific	MCP, Remedial Wastewater Discharges to Groundwater, 310 CMR 40.0045	Groundwater discharges must not erode or impair the functioning of the surficial and subsurface soils; infiltrate underground utilities, building interios or subsurface structures; result in groundwater mounding within two feet of the ground surface; or result in flooding or breakout to the surface. Concentrations of COC discharges must be below the MA groundwater quality standards and the applicable Reportable Concentrations established under 310 CMR 40.0300 and 40.1600. Additional specific requirements are given in 310 CMR 40.0045(3) for downgradient discharges.	Requirements will be taken into account when developing design, operation, and monitoring plans.

Table 4-1
Summary of Regulatory Considerations
J-3 Range Groundwater Plume RRA Plan

AUTHORITY/ TYPE	PROVISION	SYNOPSIS	ACTION TO BE TAKEN IN CONSIDERATION
Federal/ Location Specific	Wetlands Executive Order (EO) 11990; 40 CFR 6, Appendix A; 40 CFR 6.302(a)	Federal agencies are required to minimize the destruction, loss, and degradation of wetlands, and beneficial values of wetlands.	The J-3 Wetland is located south of the J-3 Range and north of Snake Pond. This requirement will be met if there is a direct or indirect impact, as these terms are defined in the EO, to this wetland. The Army will minimize harm to wetlands to the extent possible.
State/Location Specific	MADEP Wetlands Protection Act, M.G.L. c.131, Section 40 and 310 CMR 10.00	Outlines requirements necessary to work within 100 feet of a coastal or inland wetland and within 200 feet of a river. Governs all work involving filling, dredging, or alteration of wetlands, banks, land under water bodies, land subject to flooding, and riverfront areas.	The J-3 Wetland is located south of the J-3 Range and north of Snake Pond. This provision will be met if there is a direct or indirect impact to this wetland. The Army will minimize any harm to wetlands to the extent possible.
Federal/Action Specific	Resource Conservation and Recovery Act (RCRA) Identification of Hazardous Waste, 40 CFR 261.20 - 261.24	These requirements identify the characteristics and maximum concentrations of contaminants at which the waste would be considered characteristically hazardous waste. If a waste is determined to be hazardous, it must be managed in accordance with 40 CFR 261 - 268 requirements.	Testing of any solid waste generated will be performed in accordance with these requirements. If any solid wastes are determined to be hazardous, they will be managed in accordance with these regulations and disposed of in a RCRA Subtitle C permitted TSD facility.
State/Action Specific	Hazardous Waste Management Regulations – Requirements for Generators, 310 CMR 30.000 et seq.	A person who generates solid waste must determine whether the waste is hazardous using various methods, including the TCLP method, or application of knowledge of the hazardous characteristics of the waste based on information regarding the materials or processes used. If a waste is determined to be hazardous, it must be managed in accordance with 310 CMR 30.000 et seq.	Testing of any solid waste generated will be performed in accordance with these requirements. If any solid wastes are determined to be hazardous, they will be managed in accordance with these regulations and disposed of in a RCRA Subtitle C permitted TSD facility.

Table 4-1
Summary of Regulatory Considerations
J-3 Range Groundwater Plume RRA Plan

AUTHORITY/ TYPE	PROVISION	SYNOPSIS	ACTION TO BE TAKEN IN CONSIDERATION
State/ Action Specific	Solid Waste Management Regulations (RCRA Subtitle D), 310 CMR 19.000 et seq.	If a waste is determined to be a solid waste, it must be managed in accordance with the state regulations at 310 CMR 19.000 et seq.	Any solid wastes generated and determined to be non-hazardous will be managed in accordance with these regulations and disposed of appropriately.
State/Action Specific	MCP, Notification of Releases and Threats of Release of Oil and Hazardous Material, 310 CMR 40.0300-40.0336	Establishes requirements for notifying state and local authorities of releases or threats of releases of oil and hazardous material.	Notification of current releases has already been done. Notification of any new releases or spills will be submitted to the appropriate authorities in a manner compliant with these requirements.
Federal/Action Specific	Hazardous Waste Operations and Emergency Response, 29 CFR 1910.120	These regulations describe training, monitoring, planning, and other activities to protect the health of workers performing hazardous waste operations.	These worker protection standards would be followed to protect the health of workers if any primary or secondary wastes are determined to be RCRA characteristically hazardous.
Federal/Action Specific	Safety and Health Regulations for Construction, 29 CFR 1926, Subpart P	These regulations define safety requirements for construction and excavation activities.	Work crews will fulfill requirements, as applicable, including: • confirming absence of subsurface utilities (digsafe); • egress from excavations greater than four feet deep; • protection from falling loads and loose rock and soil; • use of warning systems for mobile equipment; and • protection from cave-in (side slopes) for employees in an excavation.

Table 4-1
Summary of Regulatory Considerations
J-3 Range Groundwater Plume RRA Plan

AUTHORITY/ TYPE	PROVISION	SYNOPSIS	ACTION TO BE TAKEN IN CONSIDERATION
Federal/ Action Specific	CWA NDPES Stormwater Discharge Requirements, 40 CFR 122.26	Establishes requirements for stormwater discharges associated with construction activities that result in a land disturbance of equal to or greater than one acre of land. The requirements include good construction management techniques; phasing of construction projects; minimal clearing; and sediment, erosion, structural, and vegetative controls to mitigate stormwater run-on and runoff.	If stormwater runoff associated with this rapid response action discharges to a surface water body, including wetlands, the runoff will be controlled in accordance with these requirements.
State/Action Specific	Stormwater Discharge Requirements, 314 CMR 3.04 and 314 CMR 3.19	Requires that stormwater discharges associated with construction activities be managed in accordance with the general permit conditions of 314 CMR 3.19 so as not to cause a violation of Massachusetts surface water quality standards in the receiving surface water body (including wetlands).	If stormwater runoff associated with remedial action construction, operation or maintenance activities discharges to a surface water body, including wetlands, the runoff will be controlled in accordance with these requirements.
State/Action Specific	Massachusetts Air Pollution Control Regulations [310 CMR 6.00 – 7.00]	Construction activities could trigger Massachusetts Air Pollution Control Regulations (310 CMR 6.00 – 7.00). These regulations set emission limits necessary to attain ambient air quality standards.	Engineering controls, such as dust suppression, would be used as necessary to comply with these regulations for particulate emissions during site construction activities.

CFR = *Code of Federal Regulations*
CMR = *Commonwealth of Massachusetts Regulations*
COC = contaminant of concern
CWA = Clean Water Act
DOD = U.S. Department of Defense
EO = Executive Order
EPA = Environmental Protection Agency
ETR = extraction, treatment, and reinjection
FR = Federal Register

MA = Massachusetts
MADEP = Massachusetts Department of Environmental Protection
MCL = maximum contaminant level
MCP = Massachusetts Contingency Plan
M.G.L. = Massachusetts General Law
MMCL = Massachusetts maximum contaminant level
MMR = Massachusetts Military Reservation
NPDES = National Pollutant Discharge Elimination Act
RCRA = Resource Conservation and Recovery Act
RRA = rapid response action
SDWA = Safe Drinking Water Act
TCLP = Toxicity Characteristic Leaching Procedure
TSD = treatment, storage, and disposal

Table 5-1
Model-Predicted Mass Capture of the FS-12 EDB Plume

Model Simulation	Total Aqueous and Adsorbed Mass (kg)	Total Mass Captured in 20 Years	% of Mass Captured in 20 Years	Total Mass Captured in 5.5 Years	% of Mass Captured in 5.5 Years
SE Range Model with 2003 CH2M HILL Plume Shell Avg Conditions	1.16	1.156	99.69	1.034	89.13
SE Range Model with 2003 CH2M HILL Plume Shell Avg Conditions with 100 gpm	1.16	1.156	99.66	1.032	88.92
FS-12 Design Model with 2003 CH2M HILL Plume Shell Avg Conditions	1.16	1.138	98.14	0.963	83.03
FS-12 Design Model with 2003 CH2M HILL Plume Shell Avg Conditions with 100 gpm	1.16	1.148	98.96	0.975	84.02

Notes:
Avg = average
EDB = ethylene dibromide
gpm = gallons per minute
kg = kilograms

Table 5-2
Statistical Comparison Between Field Parameters for FS-12 and J-3 Range Groundwater

	Fuel Spill-12			J-3 Range			Tests			Two-Sample Tests		
Parameters	**n**	**mean**	**median**	**n**	**mean**	**median**	**Modified Levene Equal Variance**	**Omnibus Normality**	**Test**	**Probability Level**	**Result**	**Significant Difference?**
pH	221	6.16	6.11	614	5.58	5.58	Cannot Reject	Reject	Wilcoxon Rank-Sum	0	Reject H_0	Yes
Temperature (°C)	221	11.89	11.57	620	11.11	11.02	Cannot Reject	Reject	Wilcoxon Rank-Sum	0	Reject H_0	Yes
Dissolved Oxygen (mg/L)	220	7.91	9.02	621	9.58	10.34	Cannot Reject	Reject	Wilcoxon Rank-Sum	0	Reject H_0	Yes
Oxidation-Reduction Potential (mV)	221	266.1	279.5	621	215.7	210.0	Reject	Reject	Kolmogorov-Smirnov	NA	Reject H_0	Yes
Specific Conductance (µS/cm)	221	77.4	71.0	621	75.8	66.0	Cannot Reject	Reject	Wilcoxon Rank-Sum	0	Reject H_0	Yes
Turbidity (ntu)	221	26.2	4.10	613	6.71	0.74	Reject	Reject	Kolmogorov-Smirnov	NA	Reject H_0	Yes

°C = degrees Celsius

H_0 = null hypothesis

mg/L = milligrams per liter

mV = millivolts

ntu = nephelometric turbidity units

n = number of observations

µS/cm = microsiemens per centimeter

Table 5-3

Groundwater Data Collected within 250 Meters of the J-3 Range

Method Type	Analyte	Units	Minimum	Minimum Detected Result	Maximum Detected Result	Mean (including non-detects)	Mean (excluding non-detects)	Number of Detections	Number of Non Detections	Number of Usable Samples
WetC	ALKALINITY, BICARBONATE (AS CACO3)	mg/L	ND	1	160	10.4	10.7	303	9	312
WetC	ALKALINITY, CARBONATE (AS CACO3)	mg/L	ND	23	23	0.0737	23	1	311	312
WetC	ALKALINITY, TOTAL (AS CACO3)	mg/L	ND	1	160	10.2	10.9	335	45	380
WetC	CHLORIDE (AS CL)	mg/L	0.81	0.81	151	10.4	10.4	338	0	338
WetC	HARDNESS (AS CACO3)	mg/L	ND	5	46.2	1.31	17.5	28	346	374
WetC	NITROGEN, AMMONIA (AS N)	mg/L	ND	0.0011	1.3	0.0432	0.0704	181	189	370
WetC	NITROGEN, KJELDAHL, TOTAL	mg/L	ND	0.182	2.4	0.384	1.33	2	8	10
WetC	NITROGEN, NITRATE (AS N)	mg/L	ND	0.00657	0.633	0.13	0.134	61	11	72
WetC	NITROGEN, NITRATE-NITRITE	mg/L	ND	0.01	9.9	0.328	0.398	266	58	324
WetC	NITROGEN, NITRITE	mg/L	ND	0.00015	0.001	0.00887	0.000485	15	57	72
WetC	PHOSPHORUS, DISSOLVED ORTHOPHOSPHAT	mg/L	ND	0.07	0.13	0.078	0.102	7	18	25
WetC	PHOSPHORUS, TOTAL (AS P)	mg/L	ND	0.0031	0.154	0.0242	0.0247	52	5	57
WetC	PHOSPHORUS, TOTAL PO4 (AS P)	mg/L	ND	0.00174	0.05	0.0126	0.0137	42	7	49
WetC	PHOSPHORUS, TOTAL PO4 (AS PO4)	mg/L	ND	0.01	0.4	0.0252	0.0415	165	150	315
WetC	SULFATE (AS SO4)	mg/L	1.7	1.7	64.2	6.48	6.48	338	0	338
WetC	SUSPENDED SOLIDS (RESIDUE, NON-FILT	mg/L	ND	0.2	42.5	4.97	5.95	29	23	52
WetC	TOTAL DISSOLVED SOLIDS	mg/L	ND	11	110	51.5	55	45	4	49
WetC	TOTAL ORGANIC CARBON	mg/L	ND	0.29	6.6	0.458	1.05	150	236	386
MET	IRON	mg/L	ND	0.0524	15	1.39	3.54	12	19	31
MET	IRON (TOTAL)	mg/L	ND	0.018	135	2.11	4.67	209	257	466
MET	MANGANESE	mg/L	ND	0.00056	1.2	0.156	0.192	25	6	31
MET	MANGANESE (TOTAL)	mg/L	ND	0.00055	2.27	0.131	0.146	416	50	466

Note: the MEAN is calculated using the Detection Limit as the value for samples that did not have a detectable concentration

Date range: 01/01/80 - 03/10/04, Matrix: Groundwater, Field Duplicate samples were included and averaged with the normal sample in the mean calculation

Table 5-4
J-3 Range Treatment Options Relative Capital Cost Comparison

Options	Capital Equipment Required	Estimated Installed Cost	Media Changes Required	Estimated Material Replacement Cost Per Year	Interface/Utilization of Existing FS-12 Treatment System	Relative Cost (Rounded)
FBR	FBR	$200,000	Assume Carbon Replaced 1 time/yr (8,000 lb @ $0.80 / lb)	$6,400	Interface at existing effluent system.	
	Two 4,000 lb GAC Units	$80,000			Utilize existing FS-12 building footprint.	
	Sand Filter/Backwash	$100,000				
	Demo to FS-12	$50,000				
		$430,000		$6,400		**$436,000**
GAC	Four 4,000 lb GAC Units Std Carbon	$150,000	Perchlorate Trmt: Std Carbon Replaced 1.8 times/yr (30,000 BV)[3] RDX Trmt: Std Carbon Replaced 0.2 times/yr (300,000 BV)[4] (16,000 lb @ $0.80 / lb) - Typical Std Carbon Price	$25,600	Use existing Backwash Pump, Sedimentation Tank, Effluent Tank and Pump. GAC units to occupy existing maintenance cage area.	**$176,000**
	Two 4,000 lb Tailored GAC & Two 4,000 lb Std GAC Units	$182,000	Perchlorate Trmt: Tailored GAC Replaced 0.3 times/yr (178,000 BV)[5] (8,000 lb @ $4.00 / lb) - Assumed Tailored GAC Price RDX Trmt: Std Carbon Replaced 0.2 times/yr (300,000 BV)[4] (8,000 lb @ $0.80 / lb) - Typical Std Carbon Price	$10,880	Use existing Backwash Pump, Sedimentation Tank, Effluent Tank and Pump. GAC units to occupy existing maintenance cage area.	**$193,000**
IX	Two 2,800 lb IX Units No Resin Regen + Two Std 4,000 lb GACs	$225,000	Perchlorate Trmt: Resin Replaced 1 time/yr (52,000 BVs)[6] - No Regen (5,600 lb @ $3.75 / lb) - Based on DOW Resin Price RDX Trmt: Std Carbon Replaced 0.2 time/yr (300,000 BV)[4] (8,000 lb @ $0.80 / lb) - Typical Std Carbon Price	$22,280	Use existing Backwash Pump, Sedimentation Tank, Effluent Tank and Pump. IX system to occupy existing maintenance cage area.	**$247,000**

Notes:
1) This cost comparison is preliminary and is intended to compare the cost differences of treatment equipment only. Additional cost would be incurred for extraction well pumps and piping, as well as the tie-in interface at the existing effluent system; however, these additional costs are expected to be similar for all options.
2) The cost comparison does not include engineering, design, management, or O&M associated costs.
3) Based on average of 20,000 BV and 40,000 BV from RSSCT#1 (Sept. 2003, MMR-7921) and RSSCT#2 (April 2004, MMR-8615), respectively.
4) Based on results in RSSCT #2 (April 2004, MMR-8615).
5) Based on average of 77k, 170k, 270k, and 195k BVs from RSSCT #1 (Sept. 2003, MMR-7921) and RSSCT #2 (April 2004, MMR-8615).
6) Based on typical operating history and fouling rate of U.S. Filter field systems (from teleconference).

BV = bed volume
Demo = Demolition (of obsolete equipment)
DOW = DOW Chemical Corporation
FBR = fluidized bed reactor
GAC = granular activated carbon
lb = pound
IX = ion exchange
O&M = operations and maintenance
Regen = regeneration
Std = standard